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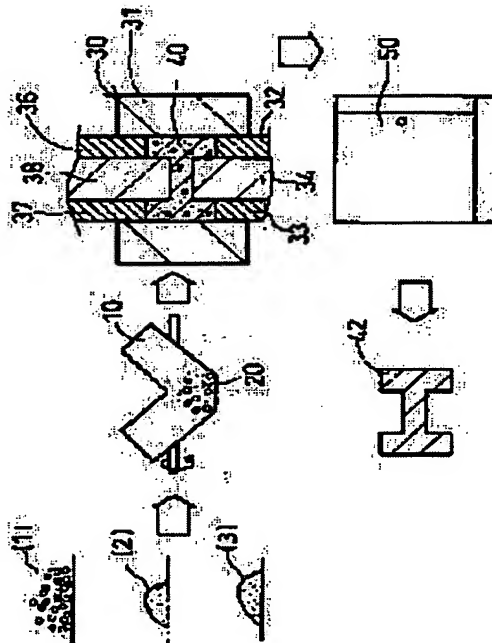
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(54) SOFT MAGNETIC POWDER MATERIAL, SOFT MAGNETIC MOLDED ARTICLE, AND METHOD FOR PRODUCING SOFT MAGNETIC MOLDED ARTICLE

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a soft magnetic powder material which is excellent in high-temperature strength and separability from a mold and has magnetic characteristics (magnetic permeability, saturated magnetic flux density, etc.), and electrical characteristics (resistivity, etc.), compatible with a good balance at a high level; a soft magnetic molded article prepared from the powder material; and a method for producing a soft magnetic molded article.

SOLUTION: This soft magnetic powder material is a mixture consisting mainly of (1) iron powder particles covered with an insulation film with high electrical insulation properties, (2) a polyamide resin, and (3) a thermoplastic resin having a melting point of 200°C or higher. the soft magnetic molded article is prepared by pressing and then heating the powder material.



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CLAIMS

[Claim(s)]

[Claim 1] The soft magnetism powder ingredient characterized by mixing the iron system powder particle to which electric insulation has a high insulating coat, polyamide system resin, and thermoplastics with the melting point of 200 degrees C or more as a major component.

[Claim 2] The thermoplastics which has the melting point of 200 degrees C or more in claim 1 is a soft magnetism powder ingredient characterized by being polyphenylene sulfide system resin.

[Claim 3] It is the soft magnetism powder ingredient which makes a soft magnetism powder ingredient 100%, and is characterized by a resin total amount being 0.1 - 3.0wt% in claim 1 or claim 2 when the sum total of polyamide system resin and thermoplastics with the melting point of 200 degrees C or more is made into a resin total amount.

[Claim 4] When the sum total of polyamide system resin and thermoplastics with the melting point of 200 degrees C or more is made into a resin total amount and a resin total amount is made into 100%, in any 1 term of claim 1 - claim 3, the rate that polyamide system resin occupies among resin total amounts Soft magnetism powder ingredient characterized by being 1 - 99wt% and the percentage that thermoplastics with the melting point of 200 degrees C or more occupies being 1 - 99wt%.

[Claim 5] The soft magnetism Plastic solid characterized by for electric insulation performing pressurization and heating and forming it to said soft magnetism powder ingredient using the soft magnetism powder ingredient currently mixed considering the iron system powder particle which has a high insulating coat, polyamide system resin, and thermoplastics with the melting point of 200 degrees C or more as a major component.

[Claim 6] The manufacture approach of the soft magnetism Plastic solid characterized by carrying out in order the 1st process which electric insulation pressurizes the iron system powder particle which has a high insulating coat, polyamide system resin, and thermoplastics with the melting point of 200 degrees C or more to said soft magnetism powder ingredient using the soft magnetism powder ingredient currently mixed as a major component, and forms a green compact, and the 2nd process which heats said green compact.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates to the manufacture approach of a soft magnetism powder ingredient, a soft magnetism Plastic solid, and a soft magnetism Plastic solid. This invention is suitable for manufacture of the soft magnetism Plastic solid used by hot environments.

[0002]

[Description of the Prior Art] In recent years, its attention is paid to the technique using the soft magnetism powder ingredient which mixed resin powder with powder-like soft magnetic materials (mainly high grade iron powder) as an ingredient of the magnetic-path formation member represented by motor cores (a rotor core, stator core, etc.). A soft magnetism Plastic solid is formed by performing pressurization and heating to this soft magnetism powder ingredient. Resin powder has the function as a binder to combine an iron system powder particle, and the function to plan electric insulation between iron system powder particles. If electric insulation between iron powder powder particles is planned, when an alternating magnetic field will act on a soft magnetism Plastic solid, electrical properties (specific resistance etc.) become good and the advantage which can reduce the eddy current loss in a soft magnetism Plastic solid is acquired.

[0003] Although the above-mentioned soft magnetism powder ingredient is fabricated with a die, as a merit of a reason A For the ingredient yield, good -> low cost-ization is very possible B. A steel plate is compared with the method which carries out a laminating. Small [of -> soft magnetism Plastic solid with the high configuration degree of freedom of a soft magnetism Plastic solid], low-cost-izing -- possible C process compaction -- possible -> -- low-cost-izing -- possible D As compared with the method to which the laminating of the steel plate is carried out, -> earth environmental protection with sufficient recycle nature, resource effective use, etc. are mentioned.

[0004]

[Problem(s) to be Solved by the Invention] However, although the above-mentioned soft magnetism powder ingredient is fabricated, it is A as a demerit of a reason. Reservation (especially under hot environments) of the soft magnetism Plastic solid which fabricated the soft magnetism powder ingredient on the strength is not easy. It is because the resinous principle is contained in the soft magnetism powder ingredient.

[0005] ** The device for picking out easily the soft magnetism Plastic solid which fabricated the soft magnetism powder ingredient from a die is required. In case the resinous principle contained in the soft magnetism powder ingredient is heating, it is for adhering to the cavity mold face of a die.

[0006] ** If resin powder is added by the soft magnetism powder ingredient, although the electrical properties (specific resistance etc.) as a soft magnetism material will improve, since resin is lacking in permeability, the magnetic properties (permeability, saturation magnetic flux density, etc.) of a soft magnetism Plastic solid fall. Then, the technical problem that both an electrical property and magnetic properties must be reconciled on high level with sufficient balance occurs.

[0007] As especially A showed, the low strength under hot environments serves as a neck, and the

adoption to the application as which reinforcement is requested like a motor core is difficult, and does not have the carried-out example.

[0008] Moreover, about I, it can respond by mixing lubricant with the lubrication of the cavity mold face of a die, or the soft magnetism powder ingredient itself. However, in this case, in order to add or apply lubricant, a problem is in the reinforcement of cost, productivity, and a soft magnetism Plastic solid.

[0009] So, in order to adopt the soft magnetism powder ingredient with which resin powder was mixed, the technical problem of above-mentioned A, I, and U must be solved.

[0010] This invention is made in view of the above-mentioned actual condition, and it extracts from the improvement in on the strength under hot environments, and a die, and let it be a technical problem to offer the manufacture approach of the soft magnetism powder ingredient which does so the effectiveness that both improvement in a sex, magnetic properties (permeability, saturation magnetic flux density, etc.), and electrical properties (specific resistance etc.) may be reconciled on high level with sufficient balance, a soft magnetism Plastic solid, and a soft magnetism Plastic solid.

[0011]

[Means for Solving the Problem] It is characterized by mixing the soft magnetism powder ingredient concerning this invention considering the iron system powder particle to which electric insulation has a high insulating coat, polyamide system resin, and thermoplastics with the melting point of 200 degrees C or more as a major component.

[0012] The soft magnetism Plastic solid concerning this invention is characterized by for electric insulation performing pressurization and heating and forming it to a soft magnetism powder ingredient, using the soft magnetism powder ingredient currently mixed considering the iron system powder particle which has a high insulating coat, polyamide system resin, and thermoplastics with the melting point of 200 degrees C or more as a major component.

[0013] The manufacture approach of the soft magnetism Plastic solid concerning this invention is characterized by carrying out in order the 1st process which electric insulation pressurizes the iron system powder particle which has a high insulating coat, polyamide system resin, and thermoplastics with the melting point of 200 degrees C or more to a soft magnetism powder ingredient using the soft magnetism powder ingredient currently mixed as a major component, and forms a green compact, and the 2nd process which heats a green compact.

[0014] Since lubricity contains good polyamide system resin, a soft magnetism powder ingredient extracts from a die after shaping, and a sex is secured. Since a soft magnetism powder ingredient contains thermoplastics with the melting point of 200 degrees C or more represented by polyphenylene SARUFAIDO, the reinforcement under hot environments is secured. Furthermore, both magnetic properties (permeability, saturation magnetic flux density, etc.) and electrical properties (specific resistance etc.) may be reconciled on high level with sufficient balance.

[0015]

[Embodiment of the Invention] - An iron system powder particle is for securing the magnetic properties (permeability, saturation magnetic flux density, etc.) of a soft magnetism Plastic solid. It is desirable from the field of reservation of magnetic properties that it is large as mean particle diameter of an iron system powder particle in the range which does not spoil compression-molding nature. As mean particle diameter of an iron system powder particle, although 70-500 micrometers and 100-350 micrometers are employable also in 30-2000 micrometers and 70-1000 micrometers, it is not limited to these. what has the purity of the iron from the point of securing magnetic properties high, as an iron system powder particle -- employable -- iron -- 90wt(s)% and more than 95wt% -- what is included is desirable. Depending on the case, a Fe-Si system and a Fe-Co system are also employable as an iron system powder particle. As an iron system powder particle, it is un-spherical and a variant thing, such as an indeterminate form which has a part for irregular concave or heights, can be adopted. In this case, it is expectable that the amount of [the irregular concave of an iron system powder particle or] heights hold a resinous principle. as the manufacture approach of an iron system powder particle -- a molten metal -- powdering -- methods (the water atomizing method, the gas atomizing method, etc.), reduction (gas reduction method etc.), the mechanical grinding method, etc. are employable. By the gas atomizing

method, inert gas, such as nitrogen and argon gas, and air are employable.

[0016] - If an iron system powder particle is a globular form-like when an iron system powder particle, polyamide system resin, and thermoplastics (henceforth the 2nd thermoplastics) with the melting point of 200 degrees C or more are mixed and it considers as mixed powder Since a resinous principle and an iron system powder particle have the large specific gravity difference, in case it mixes, a specific gravity difference originates and separates into the specific gravity difference of a resinous principle and an iron system powder particle, and there is a possibility that homogeneity miscibility may be spoiled. If this point and an iron system powder particle are the variant configurations which have a part for irregular concave or heights, in case polyamide system resin, the 2nd thermoplastics, and an iron system powder particle will be mixed, the effectiveness of making an iron system powder particle holding resin powder can be expected. Consequently, in case mixed powder is formed, it can contribute to suppressing separation resulting from the specific gravity difference of a resinous principle and an iron system powder particle, and it becomes advantageous to securing the homogeneity dispersibility in mixed powder. Also in this semantics, the smaller one of the mean particle diameter of polyamide system resin and the mean particle diameter of the 2nd thermoplastics is more desirable than the mean particle diameter of an iron system powder particle.

[0017] - The insulating coat with high electric insulation is formed in the front face of an iron system powder particle. An insulating coat is for raising the specific resistance of a soft magnetism powder ingredient, making small the eddy current loop formation which originates in an alternating magnetic field and is produced in a soft magnetism Plastic solid, when an alternating magnetic field acts on a soft magnetism Plastic solid, and making eddy current loss small. Therefore, as for an insulating coat, what has high electric insulation is desirable. As an insulating coat, the thing of the whole region of the front face of an iron system powder particle especially covered by 2/3 or more is [1/2 or more] desirable. The thing of the front face of an iron system powder particle mostly covered by the whole region as an insulating coat is desirable.

[0018] - As an insulating coat, the phosphoric acid system coat formed by phosphoric acid chemical conversion can be illustrated. As a phosphoric acid system coat, a well-known phosphoric acid system coat can be adopted, and the insulating coat of the phosphoric acid system which has a phosphoric acid component, a way acid component, and a magnesia component can be illustrated. In this case, the insulating coat of a phosphoric acid system can be formed in the front face of an iron system powder particle using the phosphoric acid system processing liquid which has phosphoric acid, a way acid, and a magnesia according to the process at which phosphoric acid system processing liquid and the front face of an iron system powder particle are contacted, and the process dried after that. Furthermore, the insulating coat of an iron phosphate system, the insulating coat of a phosphoric acid zinc system, the insulating coat of a phosphoric acid manganese system, etc. may be adopted. Although it can choose suitably as thickness of an insulating coat, and 5-5000nm can be adopted and 5-1000nm and 5-500nm can be adopted if reservation of specific resistance, reservation of permeability, etc. are taken into consideration, it is not limited to these. If the thickness of an insulating coat is too thin, although magnetic properties, such as permeability, will improve, specific resistance falls and the eddy current loss of a soft magnetism Plastic solid tends to become large. On the other hand, if the thickness of an insulating coat is too thick, although specific resistance is secured and eddy current loss can be stopped, magnetic properties, such as permeability, fall. The thickness of an insulating coat is determined in consideration of these situations.

[0019] - (Polyamide PA) system resin has an amide group in the molecular structure, and the melting point is comparatively low thermoplastics and it is excellent in lubricity. As polyamide system resin, PA6, PA66, PA11, PA12, and PA46 are mentioned, and the copolymer which contains these at least two sorts further is mentioned. Generally that whose melting points are 100-200 degrees C and 130-180 degrees C can be used for polyamide system resin.

[0020] - As the 2nd thermoplastics, thermoplastics with the melting point of 250 degrees C or more, thermoplastics with the melting point of 260 degrees C or more, or thermoplastics with the melting point of 270 degrees C or more is employable. As the 2nd thermoplastics, what has the melting point higher

than polyamide system resin is employable. As such 2nd thermoplastics, polyphenylene sulfide system resin is employable. The melting point is thermoplastics which has the crystallinity which was highly excellent in thermal resistance, and polyphenylene sulfide (it is also called Following PPS) has good thermal resistance and electric insulation under an elevated-temperature field. A straight chain mold or a bridge formation mold is sufficient as polyphenylene sulfide.

[0021] - It is better to join the insulating coats of an iron system powder particle directly generally rather than it makes a resinous principle intervene in order to secure the bonding strength of an iron system powder particle. However, since a resinous principle does not exist in this case, it extracts from a die, and a sex is not enough, in the case without a mold, a Plastic solid is damaged or productivity falls. The 2nd thermoplastics when the melting point is higher than polyamide system resin The operation to which the 2nd thermoplastics stops that polyamide system resin carries out a superfluous flow of it in the boundary region of an iron system powder particle in the time of heating or use since it is hard to fuse the 2nd thermoplastics rather than polyamide system resin is expectable. Therefore, it can suppress that polyamide system resin does not carry out a superfluous flow on the boundary of an iron system powder particle, therefore polyamide system resin covers the insulating coat of an iron system powder particle superfluously.

[0022] In a soft magnetism powder ingredient, a powdered thing is desirable as a gestalt of polyamide system resin and the 2nd thermoplastics. If the mean particle diameter of resin powder is too large, while it is disadvantageous in the field of reservation of high temperature strength as the above-mentioned polyamide system resin and the 2nd thermoplastics, also in the field which may reconcile both magnetic properties (permeability, saturation magnetic flux density, etc.) and electrical properties (specific resistance etc.) on high level with sufficient balance, it is disadvantageous. Polyamide system resin and the 2nd thermoplastics have the desirable one where particle size is smaller than an iron system powder particle. As the above-mentioned polyamide system resin and the 2nd thermoplastics, it can be referred to as 50 micrometers or less still more desirably, and 100 micrometers or less 200 micrometers or less are desirably good also as 10 micrometers or less still more desirably depending on the case. Especially, as polyamide system resin and the 2nd thermoplastics, a thing 50 micrometers or less can adopt still more desirably desirably 100 micrometers or less of 200 micrometers or less of things which occupy 80wt% among each resin still more desirably. When mean particle diameter of polyamide system resin is set to D1 and mean particle diameter of the 2nd thermoplastics is set to D2, $D1=D2$ and $D1^{**}D2$ are sufficient, and $D1<D2$, $D1>D2$ is sufficient. In this case, the mean particle diameter of an iron system powder particle is larger than the mean particle diameter of resin powder.

[0023] - If the resin total amount occupied into a soft magnetism powder ingredient increases, while the rate of an iron system powder particle will fall relatively and magnetic properties (permeability, saturation magnetic flux density, etc.) will fall, high temperature strength also falls. Although magnetic properties will improve since the rate of an iron system powder particle becomes high relatively if a resin total amount decreases, while the function as a binder on which an iron system powder particle is pasted up falls, in order that polyamide system resin may decrease in number relatively, the lubricity to a die falls. the time of making a soft magnetism powder ingredient into 100% in consideration of the above-mentioned point -- as the resin total amount of polyamide system resin and the 2nd thermoplastics -- desirable -- less than [3wt%] -- further -- desirable -- less than [1wt%] -- it is made to less than [0.7wt%] 0.8wt(s)% still more desirably. For example, as a resin total amount, it is 0.1 - 1.0wt% 0.1 - 2.0wt% 0.1 - 3.0wt%. However, it is not limited to these.

[0024] - as the rate that polyamide system resin occupies a resin total amount for it among resin total amounts when the sum total of polyamide system resin and the 2nd thermoplastics is made into 100% -- as 1 - 99wt% and the rate that can make 20 - 80wt% especially and the 2nd thermoplastics occupies among resin total amounts -- 1 - 99wt% -- it is 20 - 80wt% especially. Although the 2nd thermoplastics is advantageous to securing the high temperature strength of a soft magnetism Plastic solid, if more 2nd thermoplastics is added, in order that the addition of polyamide system resin may decrease relatively, lubricity runs short and there is fault which is extracted at the time of extracting a Plastic solid from the shaping cavity of a die, and $**$ increases. Although lubricity will improve, it will extract at the time of

extracting a Plastic solid from the shaping cavity of a die and ** may be reduced since the addition of polyamide system resin increases relatively if the 2nd thermoplastics is added fewer, there is fault to which the high temperature strength of a soft magnetism Plastic solid falls. Then, as the addition of polyamide system resin, and an addition of the 2nd thermoplastics, the above-mentioned rate is desirable.

[0025] - Using the above-mentioned soft magnetism powder ingredient, to the soft magnetism powder ingredient, the above-mentioned soft magnetism Plastic solid performs pressurization and heating, and is formed. Pressurization and heating may be performed according to an individual, and you may carry out to coincidence. In this case, it can form by carrying out the 2nd process which heats and carries out curing of the green compact the 1st process which presses a soft magnetism powder ingredient with dice, such as metal mold, and forms a green compact, and after that. As for the 1st process using a die, it is desirable to carry out in an ordinary temperature field. If a soft magnetism powder ingredient is pressurized in an ordinary temperature field, it is suppressed that a resinous principle adheres to the cavity mold face of a die, and it can carry out mold omission of the green compact good from the cavity mold face of a die. Although it can choose suitably as welding pressure in the 1st process according to the configuration of classes, such as an iron system powder particle, and a soft magnetism Plastic solid, 50MPa-1000MPa (1 kgf/cm²*0.1 if MPa about 500 kgf/cm² - about 10000 kgf/cm²) is employable. 100MPa-800MPa (about 1000 kgf/cm² - about 8000 kgf/cm²) is especially employable. Since the resin contained in the soft magnetism powder ingredient may paste the cavity mold face of dice, such as shaping metal mold, when it is heated, while a soft magnetism powder ingredient is temporarily pressurized at the 1st process, the mold omission nature from a die becomes less easy, and productivity falls.

[0026] As pressurization time amount in the 1st process, 0.1 - 20 seconds, 0.5 - 10 seconds, and 0.5 - 5 seconds are employable. For improvement in productivity, the shorter one of pressurization time amount is desirable. However, it is not limited to the value described above as welding pressure and pressurization time amount. Although an atmospheric-air ambient atmosphere is employable as an ambient atmosphere of the 1st process, depending on the case, it is good also as an inert gas ambient atmosphere. It is desirable to melt the both sides of polyamide system resin and the 2nd thermoplastics, and to raise the adhesive property over an iron system powder particle at the 2nd process. Therefore, the 2nd process can be performed where a green compact is heated. Since polyamide system resin has the relatively low melting point, it is imagined to be what is easy to flow in the grain boundary between iron system powder particles at the time of heating. Thus, if polyamide system resin flows and it exists in the front face of an iron system powder particle the shape of a piece, and in the shape of film, it will be imagined as a thing advantageous to being easy to function effectively as an insulating coat like a phosphoric acid system coat, raising the specific resistance of a soft magnetism powder ingredient and a soft magnetism Plastic solid as compared with the case where polyamide system resin is granular, and stopping eddy current loss. However, when polyamide system resin carries out a superfluous flow in the grain boundary between iron system powder particles, there is a possibility that the magnetic properties of a soft magnetism Plastic solid may fall, and there is a possibility of reducing the bond strength of iron system powder particles further. For this reason, in the semantics which secures the reinforcement of a soft magnetism Plastic solid in the semantics which secures the magnetic properties of a soft magnetism Plastic solid, a superfluous flow of polyamide system resin is not desirable.

[0027] When whenever [stoving temperature] is too high, the resin contained in the soft magnetism powder ingredient deteriorates, or there is a possibility that an insulating coat may deteriorate. If whenever [stoving temperature] is too low, the adhesive strength by the resin contained in the soft magnetism powder ingredient will not improve. In consideration of such a point, 350 degrees C or less 450 degrees C or less can be adopted still more desirably as whenever [stoving temperature]. Therefore, at the 2nd process, 350 degrees C or less 450 degrees C or less can be adopted still more desirably. As lower limit temperature in the 2nd process, it is desirable to exceed the melting point of 2nd thermoplastics, therefore it can carry out according to the class of the 2nd thermoplastics to 250 degrees C or more, 270 degrees C or more, 280 degrees C or more, or 290 degrees C or more. Therefore,

as whenever [stoving temperature / when heating a soft magnetism powder ingredient], 250-450-degree C 270-350 degrees C can be illustrated especially. Although an atmospheric-air ambient atmosphere is employable as an ambient atmosphere of the 2nd process, depending on the case, it is good also as an inert gas ambient atmosphere. Generally, since the 2nd process is not performed within dice, such as metal mold, and performs in the condition (condition of not restraining) of having left it, it does not have especially the need of taking into consideration the mold omission nature to dice, such as shaping metal mold. With dice, such as shaping metal mold by which the temperature control was carried out depending on the case, it may heat to compacting and coincidence of a soft magnetism powder ingredient, and curing may be performed.

[0028] - the electromagnetism represented by a motor, the electro-magnetic valve, etc. as a soft magnetism Plastic solid -- it can use for the magnetic-path formation member used for an actuator. As a magnetic-path formation member applied to a motor, a rotor core, a stator core, etc. are employable. As a motor, various motors, such as a motor for anti-lock brake systems, a power steering motor, a windshield wiper motor, a motor for window regulators, and a motor for sunroofs, are mentioned. As a soft magnetism Plastic solid, the magnetic-path formation member used by various sensors, such as a torque sensor and a displacement sensor, is mentioned. Although the soft magnetism Plastic solid fabricated with the soft magnetism powder ingredient concerning this invention fits the soft magnetism Plastic solid used under hot environments like engine rooms, such as a car, since the mold omission nature from the shaping cavity of a die also does good effectiveness so, it is not limited only to the soft magnetism Plastic solid used by hot environments.

[0029]

[Example] Hereafter, the example of this invention is explained concretely.

[0030] Drawing 1 shows a manufacture process typically. (1), (2), and (3) were used as a start raw material.

(1) Somaloy550 of HEGANESU was used as metal powder. this metal powder -- the front face of the iron system powder particle (iron powder, Fe-0.01wt% below C, H2 loss 0.08wt%, particle size : about 20-200 micrometers) of a high grade -- phosphoric acid -- formation -- the laminating of the phosphoric acid system coat is carried out by coat processing. what a phosphoric acid system coat functions on as an insulating coat with high electric insulation -- it is -- an iron system powder particle -- the laminating is mostly carried out to all front faces. An iron system powder particle secures a soft magnetism property. A phosphoric acid coat has high electric insulation resistance, and is advantageous to reducing the eddy current loss of the soft magnetism Plastic solid when acting an alternating magnetic field.

(2) Polyamide system resin (mean particle diameter: about 10 micrometers) was used. This mean particle diameter means the most frequent degree value in particle size distribution. Polyamide system resin is thermoplastics, and its lubricity is good and it can function as powder lubricant. Polyamide system resin can contribute also for securing the bond strength in an ordinary temperature field with an iron system powder particle. The melting point of the polyamide system resin used by this example is about 140 degrees C.

(3) PPS resin (mean particle diameter: about 18 micrometers) was used. This mean particle diameter means the most frequent degree value in particle size distribution. PPS resin functions as the 2nd thermoplastics and can contribute to bond strength with an iron system powder particle, and raising the bond strength under hot environments especially. The melting point of PPS resin is about 280 degrees C.

[0031] And as shown in drawing 1 , where specified quantity weighing capacity of the iron system powder of (1) and the resin of the shape of powder of (2) and (3) is carried out, by carrying out the rotation drive of the mixer 10, three persons were mixed for 60 minutes and the mixed powder 20 was formed. The 1st process was carried out using the soft magnetism powder ingredient which is the mixed powder 20 in the condition that an iron system powder particle, polyamide system resin, and PPS resin were mixed. That is, the soft magnetism powder ingredient was supplied in the cavity of the shaping metal mold 30 which is shaping metal mold, pressing was carried out with the shaping metal mold 30 at the room temperature, and Plastic solid 40 which is a green compact was acquired. The shaping metal

mold 30 has the cartridge-like die 31, the female mold 32 by which fitting was carried out to the die 31, and the punch 36 by which fitting was carried out to the die 31. Female mold 32 has cartridge-like the outside female mold 33 and the inside female mold 34. A punch 36 has cartridge-like the outside punch 37 and the inside punch 38.

[0032] Although the mixed powder 20 which is a soft magnetism powder ingredient in the cavity of the shaping metal mold 30 is pressurized according to this example, since the temperature when pressurizing is a room temperature, the resinous principle of the mixed powder 20 does not fuse it, but it becomes advantageous to solving the problem on which a resinous principle adheres to the cavity mold face of the shaping metal mold 30. As pressurization conditions which pressurize the mixed powder 20 which is a soft magnetism powder ingredient, welding pressure was set to 600MPa(s) (about 6000 kgf/cm²), and pressurization time amount was made into about 1 second.

[0033] Then, Plastic solid 40 which is a green compact taken out from the cavity of the shaping metal mold 30 was heated in atmospheric air with the heat treating furnace 50, curing was performed to Plastic solid 40, the 2nd process was carried out, and soft magnetism Plastic solid 42 was acquired. At the 2nd process, polyamide system resin and PPS resin will fuse with heating, and a function will be raised as a binder which combines an iron system powder particle. As heating conditions in the 2nd process, whenever [stoving temperature] was set as 300 degrees C, and heating time was set as for 60 minutes. In addition, especially pressurization is not given in the 2nd process, but Plastic solid 40 is in the condition of not restraining. Therefore, it is avoidable that Plastic solid 40 and soft magnetism Plastic solid 42 paste a partner mold at the 2nd process.

[0034] Drawing 2 copies the condition of having observed the interior of soft magnetism Plastic solid 42 after curing by EPMA. In this observed soft magnetism Plastic solid 42, when a soft magnetism powder ingredient was made into 100%, polyamide system resin was 0.3% in the weight ratio, and PPS resin was 0.3%. As shown in drawing 2, the laminating of the thin film-like phosphoric acid system coat 410 was carried out throughout the front face of the iron system powder particle 400. And the iron system powder particle 400 to which the laminating of the phosphoric acid system coat 410 was carried out was joined mutually. In this case, there were many parts which phosphoric acid system coat 410 comrades have joined. The phase 420 (field shown by the hatching line) of the shape of a piece of polyamide system resin and the phase 430 (black painting-out field) of the shape of a piece of PPS resin exist in the boundary region of the iron system powder particle 400 where the laminating of the phosphoric acid system coat 410 was carried out. According to drawing 2, seldom dissolving, but carrying out mutually-independent and existing is imagined in the phase 420 of the shape of a piece of polyamide system resin, and the phase 430 of the shape of a piece of PPS resin. According to drawing 2 R> 2, it is imagined that the phase 420 of the shape of a piece of polyamide system resin and the phase 430 of the shape of a piece of PPS resin exist in the depression part of the iron system powder particle 400. Furthermore, according to drawing 2, the gestalt by which a superfluous flow of the phase 420 of polyamide system resin is stopped with the phase 430 of PPS resin is imagined. In order to stop a superfluous flow of the phase 420 of polyamide system resin, it is guessed that it is effective that the particle size of PPS resin is larger than the particle size of polyamide system resin.

[0035] According to the trial which this invention persons performed, with the test piece which did not add resin at all although manufactured on the same conditions, although the mold omission nature from the shaping metal mold 30 is bad, since the reinforcement after curing is high, it has become clear that the bond strength of phosphoric acid system coats is high. If a superfluous flow of the phase 420 of polyamide system resin is stopped with the phase 430 of PPS resin as described above, it will be imagined as what can contribute to adhesion of phosphoric acid system coats with the high bond strength of the iron system powder particle 400 being secured, and securing the reinforcement of soft magnetism Plastic solid 42.

[0036] In the above-mentioned example, the ease of taking out at the time of taking out Plastic solid 40 from the cavity of the shaping metal mold 30 (extracting size of a pressure) poses a problem first. In this case, Plastic solid 40 needs to extract and it is necessary to make a pressure small. Generally, lubricant is applied, or a soft magnetism powder ingredient and lubricant will be mixed with the cavity mold face of

the shaping metal mold 30, and it will correspond to it. However, with this means, a problem is in cost and productivity. Moreover, there is fault to which the engine performance as soft magnetism Plastic solid 42 after curing and reinforcement fall. On the other hand, big effectiveness can be acquired to extract Plastic solid 40 into a soft magnetism powder ingredient when extracting the polyamide system resin which has a lubricant function other than binder ability like this example from the cavity of the shaping metal mold 30 as well as the function as a binder by specified quantity intrusion *****, and make it reduce a pressure.

[0037] However, when only polyamide system resin is mixed with a soft magnetism powder ingredient as resin and it is used under hot environments (for example, 180-260 degrees C) like the motor used in an engine room etc., there is fault to which the reinforcement of soft magnetism Plastic solid 42 falls remarkably. This is because operating environment temperature is over the melting point of polyamide system resin, and the bond strength by polyamide system resin can seldom be expected under hot environments. A thing required in order to solve this problem is PPS resin. The melting point of PPS resin is about 270-290 degrees C, and is higher than the above-mentioned hot-environments temperature. Therefore, in order not to fuse PPS resin in the above-mentioned hot-environments temperature, when using soft magnetism Plastic solid 42 by hot environments, the adhesive strength which PPS resin has is demonstrated as bond strength. Moreover, the polyamide system resin which is in a melting condition in hot-environments temperature has a flow barrier-function for preventing flowing superfluously in the front face of the iron system powder particle 400, and it is contributing to the improvement in on the strength under hot environments.

[0038] (Evaluation) The test piece which is soft magnetism Plastic solid 42 was produced from the soft magnetism powder ingredient, and various trials were performed. The test piece is fundamentally formed based on the above-mentioned conditions. And the relation between the addition of the polyamide system resin blended with the soft magnetism powder ingredient and PPS resin and each characteristic value was examined. Polyamide system resin is described also as PA among a drawing, and PPS resin is described also as PPS.

[0039] First, the ease of taking out of Plastic solid 40 which is a green compact from the shaping metal mold 30 after carrying out the 1st process is explained with reference to drawing 3 and drawing 4. The axis of abscissa of drawing 3 shows the addition of polyamide system resin. The axis of ordinate of drawing 3 is extracted at the time of taking out the test piece currently formed with the Plastic solid which is a green compact from the shaping metal mold 30, and shows **. In drawing 3, O shows the case where a resin total amount is 0.4wt(s)%, ** shows the case where a resin total amount is 0.6wt(s)%, and ** shows the case where a resin total amount is 0.8wt(s)%. the iron system powder particle to which the laminating of the phosphoric acid system coat is carried out while a resin total amount occupies 0.4wt(s)%, when a resin total amount makes the mixed whole powder 100% with 0.4wt(s)% -- 99.6wt(s)% -- it means occupying. When a resin total amount is O, and is 0.4wt(s)% and the addition of polyamide system resin is 0.1wt(s)%, polyamide system resin shows that PPS resin is 0.3wt(s)% at 0.1wt(s)%. Moreover, when a resin total amount is **, and is 0.6wt(s)% and the addition of polyamide system resin is 0.3wt(s)%, polyamide system resin shows that PPS resin is 0.3wt(s)% at 0.3wt(s)%. ** The example 1 of a comparison is shown. Although a phosphoric acid system coat adds polyamide system resin to the iron system powder particle (the same iron system powder particle as an example) by which the laminating is carried out, the example 1 of a comparison has not added PPS resin, and the amount of polyamide system resin. If the addition of polyamide system resin increases as shown in drawing 3, a test piece extracts, ** is decreasing and it turns out that polyamide system resin was extracted and it has contributed to reduction of ** greatly.

[0040] The axis of abscissa of drawing 4 shows the addition of PPS resin. The axis of ordinate of drawing 4 is extracted at the time of taking out the test piece currently formed with the Plastic solid which is a green compact from the shaping metal mold 30, and shows **. the iron system powder particle (the same iron system powder particle as an example) to which, as for the example 2 of a comparison, the laminating of the phosphoric acid system coat is carried out according to the trial shown in drawing 4 R> 4 -- polyamide system resin 0.6wt% -- PPS resin is not included although it has added.

As shown in drawing 4, the test piece which is a Plastic solid exceeds the addition of PPS resin, and it hardly influences **. Therefore, if a test piece extracts and only ** is considered, what is necessary will be just to add polyamide system resin to many eyes more.

[0041] Next, the tensile strength of the test piece which is a soft magnetism Plastic solid after curing is explained with reference to drawing 5 and drawing 6. The axis of abscissa of drawing 5 shows the addition of PPS resin, when a soft magnetism powder ingredient is made into 100%. The axis of ordinate of drawing 5 shows ordinary temperature tensile strength and the tensile strength in 200 degrees C. Tensile strength shows the tensile strength of the test piece currently formed with the soft magnetism Plastic solid which heated and carried out curing (300 degree-Cx 1 hour) of the green compact which compressed the soft magnetism powder ingredient on the above-mentioned pressurization conditions on the above-mentioned heating conditions. As a test for tensile strength, it carried out based on the "metallic material tension test approach" of JIS Z-2241. Although the tensile strength in a room temperature shows a high value, the reinforcement under hot environments (200 degrees C) cannot exceed 2 (**9.8MPa) easily 1 kgf/mm, but serves as a low value by the test piece group M1 M1 by which only polyamide system resin is added, i.e., the test piece group by which PPS resin is not added, so that he can understand from drawing 5. Moreover, although it is not a forge fire in the case where only polyamide system resin is added also about the test piece groups M2, M3, and M4 by which only PPS resin is added, the reinforcement under hot environments is not enough.

[0042] However, the inclination for the reinforcement under hot environments to improve is seen by using the soft magnetism powder ingredient which combined both polyamide system resin and PPS resin, and was added so that he can understand from drawing 5. It turns out that it is important to add both polyamide system resin and PPS resin collectively by these test results in order to secure the reinforcement under hot environments.

[0043] In addition, tensile strength [in / Plastic solid / which was formed with the soft magnetism powder ingredient (both polyamide system resin and PPS resin are not included) which carried out the laminating of the phosphoric acid system coat to the particle in the end of iron powder / soft magnetism / ordinary temperature] was about [about 2.6 kgf(s)/mm] two, and the tensile strength in 200 degrees C was about [about 2.6 kgf(s)/mm] two.

[0044] Moreover, the axis of abscissa of drawing 6 shows the addition of PPS resin, and the axis of ordinate of drawing 6 shows the tensile strength of the test piece which is a soft magnetism Plastic solid in 200 degrees C. As the peak field A1 of the characteristic ray A of drawing 6 shows, when a resin total amount is 0.4wt(s)% (**) and PPS resin is 0.1% (polyamide system resin: 0.3wt%), elevated-temperature tensile strength is high. As the peak field B1 of the characteristic ray B of drawing 6 shows, when a resin total amount is 0.6wt(s)% (O) and PPS resin is 0.3% (polyamide system resin: 0.3wt%), elevated-temperature tensile strength is high. As the peak field C1 of the characteristic ray C of drawing 6 shows, when a resin total amount is 0.8wt(s)% (**) and PPS resin is about 0.5% (polyamide system resin: 0.3wt%), elevated-temperature tensile strength is high. Within examined limits, if this is taken consideration, when the soft magnetism powder ingredient which is mixed powder is made into 100% and polyamide system resin is near 0.3wt%, high elevated-temperature tensile strength is obtained and it can be said that the good mixed ratio exists.

[0045] Next, the consistency of the test piece after curing of the test piece which is a Plastic solid is explained with reference to drawing 7. The axis of abscissa of drawing 7 R> 7 shows the rate of the PPS resin occupied in a resin total amount, when a resin total amount is made into 100%. Moreover, the axis of abscissa of drawing 7 also shows the addition of the polyamide system resin in a soft magnetism powder ingredient, and PPS resin, when a soft magnetism powder ingredient is made into 100%. The axis of ordinate of drawing 7 shows the consistency of the test piece after curing. In this case, welding pressure in the 1st process was set to 6000 kgf/cm2 and (600MPa) for the resin total amount 0.4wt(s)%. Even if the rate of PPS occupied in a resin total amount increased when a resin total amount was the same as shown in drawing 7, the consistency of the test piece which is a soft magnetism Plastic solid was good. When especially PPS resin was 0.1wt(s)% and 0.2wt% and 0.3wt%, the consistency of a test piece was good. in addition, the example 2 of a comparison pressurizes and heats the iron system

powder particle to which the laminating of the phosphoric acid system coat was carried out, and fabricates it -- having -- **** -- polyamide system resin -- 0.6wt(s)% -- PPS resin is not included although contained.

[0046] Next, the specific resistance after curing of the test piece which is a Plastic solid is explained with reference to drawing 8. The axis of abscissa of drawing 8 shows the rate (expressed by the shaft with 0%, 25%, 50%, 75%, and 100% of numeric value) of the PPS resin occupied in a resin total amount, when a resin total amount is made into 100%. Moreover, the axis of abscissa of drawing 8 R> 8 also shows the addition (expressed by the shaft with 0.4%, 0.3%, 0.2%, and 0.1% of numeric value) of the polyamide system resin in a soft magnetism powder ingredient, and PPS resin, when a soft magnetism powder ingredient is made into 100%. The axis of ordinate of drawing 8 shows the specific resistance of the test piece which is a Plastic solid after curing. Welding pressure in the 1st process was set to 6000 kgf/cm² and (600MPa) in this trial. Specific resistance is increasing as are shown in drawing 8 and the amount of polyamide system resin increases, when a resin total amount is the same. That is, the amount of PPS resin increases, it takes and specific resistance is falling. According to drawing 8, when polyamide system resin is 0%, specific resistance is falling considerably. For this reason, in order to make specific resistance of a test piece high and to stop eddy current loss, it can be said that the direction with many amounts of polyamide system resin is good.

[0047] As a reason which specific resistance increases as the amount of polyamide system resin increases like the test result of drawing 8, since the melting point is lower than PPS resin, polyamide system resin tends to flow in the case of heating between the iron system powder particles in which the phosphoric acid system coat is formed, and is guessed because it is easy to exist the shape of a piece, and in the shape of film rather than PPS resin. Since this polyamide system resin has high electric insulation, if it exists the shape of a piece, and in the shape of film in an iron system powder particle, it will be advantageous to restricting a current path, and will be imagined to be what raises the specific resistance of the test piece which is a soft magnetism Plastic solid.

[0048] Next, the effective permeability is explained with reference to drawing 9 and drawing 10. The axis of abscissa of drawing 9 shows the consistency of the test piece which is a soft magnetism Plastic solid after curing, and the axis of ordinate of drawing 9 shows the effective permeability of the test piece which is a soft magnetism Plastic solid after curing. moreover, a resin total amount -- 0.4 - 0.8wt% -- it considered as within the limits. In this case, when the sum total of polyamide system resin and PPS resin was made into 100%, the rate of PPS resin was changed with 0%, 25%, 50%, 62.5%, 75%, and 100%. In measuring the effective permeability, the 400Hz alternation current was energized to the toroidal coil, and where an alternating magnetic field (1.3T) is generated, it measured. As shown in drawing 9, although the consistency of the test piece which is a soft magnetism Plastic solid after curing affects the effective permeability, even if a resin total amount changes, or the addition rate of polyamide system resin and PPS resin changes and the consistency of a test piece varies somewhat, the good effective permeability is obtained.

[0049] The axis of abscissa of drawing 10 shows the resin total amount occupied into a soft magnetism powder ingredient. The axis of ordinate of drawing 10 shows the effective permeability of the test piece which is a soft magnetism Plastic solid after curing. In this case, when the sum total of polyamide system resin and PPS resin was made into 100%, the addition of PPS resin was changed with 0%, 25%, 50%, 62.5%, 75%, and 100%. The inclination for the effective permeability of a test piece to fall was seen as were shown in drawing 10 and the resin total amount increased. It is for the rate of the iron system powder particle of soft magnetism to fall. for this reason, the time of making a soft magnetism powder ingredient into 100% -- a resin total amount -- less than [1.5wt%] -- it can be said that less than [1.0wt%] is especially desirable.

[0050] Next, the effective permeability is explained with reference to drawing 11. The axis of abscissa of drawing 11 shows the consistency of the test piece which is a soft magnetism Plastic solid after curing, and the axis of ordinate of drawing 11 shows weight iron loss. In this case, when a resin total amount was made into 100%, the rate of the PPS resin occupied in a resin total amount was changed to 0%, 25%, 50%, 62.5%, 75%, and 100%. By this trial, it measured in the condition of having energized

the 400Hz alternation current to the toroidal coil, and having made it generating an alternating magnetic field (1.3T). moreover, a resin total amount -- 0.4 - 0.8wt% -- it considered as within the limits. Weight iron loss (w/kg) is total of hysteresis loss and eddy current loss. Iron loss is almost changeless, even if the addition rate of polyamide system resin and PPS resin changes and the consistency of a test piece varies somewhat, as shown in drawing 11.

[0051] A soft magnetism powder-molding object with the high reinforcement under hot environments can be acquired good [magnetic properties and an electrical property (specific resistance)], taking out a Plastic solid, and being [a Plastic solid / it] easy and carrying out it from the cavity of dice, such as shaping metal mold, by controlling the addition of the above-mentioned polyamide system resin and PPS resin according to the demand characteristics in a soft magnetism Plastic solid, as explained above.

[0052] (Example of application) Drawing 12 shows the example of application applied to the brush motor (electromagnetism actuator) which is the example of representation of a motor. The brush motor 500 has a case 501, the shaft 502 as the actuation section prepared in the case 501 pivotable, and the armature 503 held at the shaft 502. An armature 503 has the core 504 which forms a magnetic path, the armature coil 505 which is held at a core 504 and generates line of magnetic force, and the supporter 506 which holds a core 504 at a shaft 502. The brush 600 is held at the brush holder 603 in the condition of having been energized with the coil spring 602 so that it might contact from the inside toward an outside to the brush contact section 601. If a shaft 502 rotates, a centrifugal force will act on a core 504. This motor may be used under the hot environments in the engine room of a car etc. In case this motor is used by the car, car vibration acts on a core 504 besides a centrifugal force.

[0053] A core 504 is a magnetic-path formation member which forms a magnetic-path loop formation, it is formed with the soft magnetism Plastic solid concerning the above-mentioned example, and improvement in on the strength under hot environments is achieved. Even if a core 504 is used in the condition that a centrifugal force and vibration act on a core 504, for the bottom of hot environments, the reinforcement of a core 504 is fully secured.

[0054] Furthermore, since the core 504 is formed with the soft magnetism Plastic solid concerning the above-mentioned example, it is extracted from dice, such as shaping metal mold, and does so the effectiveness that both improvement in a sex, magnetic properties (permeability, saturation magnetic flux density, etc.), and electrical properties (specific resistance etc.) may be reconciled on high level with sufficient balance. the motor of not only the above-mentioned brush motor but others [this invention], and the electromagnetism of further others -- it is also applicable to an actuator.

[0055] (in addition to this) In addition to this, this invention approach and this invention equipment are not limited only to the above-mentioned example, within limits which do not deviate from a summary, are changed suitably and can be carried out.

[0056] The following technical thought can also be grasped from the above-mentioned publication.

(Additional remark term 1) The soft magnetism Plastic solid concerning each claim used by the hot environments in the engine room of a car etc. It is suitable for using it by the hot environments in an engine room etc.

(Additional remark term 2) The magnetic-path formation member concerning each claim used by the hot environments in the engine room of a car etc. It is suitable for using it by hot environments like [in an engine room].

(An additional remark term 3) The manufacture approach of the soft-magnetism Plastic solid characterized by to carry out in order the mixed process which forms the soft-magnetism powder ingredient which uses as a major component the iron system powder particle and the polyamide system resin with which electric insulation has a high insulating coat, and thermoplastics with the melting point of 200 degrees C or more, the pressurization process (the 1st process) which pressurizes to a soft-magnetism powder ingredient and form a green compact, and the heating process (the 2nd process) which heat a green compact.

(Additional remark term 4) It is the motor characterized by having the armature coil which is the motor which has a case, the shaft prepared in the case pivotable, and the armature held at the shaft, and was held at the core which forms the magnetic path formed with the soft magnetism Plastic solid which an

armature requires for each claim, and the core. It extracts from the improvement in on the strength under hot environments, and a die, and both improvement in a sex, magnetic properties (permeability, saturation magnetic flux density, etc.), and electrical properties (specific resistance etc.) may be reconciled on high level with sufficient balance.

(Additional remark term 5) the electromagnetism which has a case, the actuation section prepared in the case possible [actuation], and the core which forms a magnetic path -- the electromagnetism characterized by forming the core with the soft magnetism Plastic solid concerning each claim in an actuator -- an actuator. It extracts from the improvement in on the strength under hot environments, and a die, and both improvement in a sex, magnetic properties (permeability, saturation magnetic flux density, etc.), and electrical properties (specific resistance etc.) may be reconciled on high level with sufficient balance.

(Additional remark term 6) The mean particle diameter of the thermoplastics which electric insulation is mixed considering the iron system powder particle which has a high insulating coat, polyamide system resin, and thermoplastics with the melting point of 200 degrees C or more as a major component, and has the melting point of 200 degrees C or more is a soft magnetism powder ingredient characterized by being larger than the mean particle diameter of polyamide system resin.

(Additional remark term 7) It is the soft magnetism powder ingredient characterized by the mean particle diameter of the thermoplastics which electric insulation is mixed considering the iron system powder particle which has a high insulating coat, polyamide system resin, and thermoplastics with the melting point of 200 degrees C or more as a major component, and has the melting point of 200 degrees C or more being larger than the mean particle diameter of polyamide system resin, and the mean particle diameter of an iron system powder particle being larger than the mean particle diameter of thermoplastics with the melting point of 200 degrees C or more.

[0057]

[Effect of the Invention] As explained above, according to this invention, the manufacture approach of the soft magnetism powder ingredient which does so the effectiveness that it extracts from the improvement in on the strength under hot environments and a die, and both improvement in a sex, magnetic properties (permeability, saturation magnetic flux density, etc.), and electrical properties (specific resistance etc.) may be reconciled on high level with sufficient balance, a soft magnetism Plastic solid, and a soft magnetism Plastic solid can be offered.

[0058] According to the manufacture approach of carrying out in order the 1st process which pressurizes to a soft magnetism powder ingredient especially using the above-mentioned soft magnetism powder ingredient, and forms a green compact, and the 2nd process which heats a green compact Since it can reduce or avoid applying lubricant to the cavity mold face of a die, or mixing lubricant with a soft magnetism powder ingredient while keeping extracting a green compact from a die in the 1st process, securing a sex good and being able to aim at improvement in productivity, it is advantageous to quality improvement of a soft magnetism Plastic solid.

[0059] When thermoplastics with the melting point of 200 degrees C or more is polyphenylene sulfide system resin and a soft magnetism Plastic solid is used under hot environments, it is advantageous to securing the reinforcement of a soft magnetism Plastic solid. Furthermore, when a soft magnetism powder ingredient is made into 100% and the sum total of polyamide system resin and thermoplastics with the melting point of 200 degrees C or more is made into a resin total amount, When a resin total amount is set to 0.1-3.0wt It is advantageous to doing so the effectiveness that a resinous principle becomes suitable to an iron system powder particle, it extracts from the improvement in on the strength under hot environments, and a die, and both improvement in a sex, magnetic properties (permeability, saturation magnetic flux density, etc.), and electrical properties (specific resistance etc.) may be reconciled on high level with sufficient balance.

[Translation done.]

* NOTICES *

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] It is process drawing showing a manufacture process typically.

[Drawing 2] It is structural drawing copying the condition of having observed the internal structure of a soft magnetism Plastic solid by EPMA.

[Drawing 3] It is the graph which extracts with the addition of polyamide system resin and shows relation with **.

[Drawing 4] It is the graph which extracts with the addition of PPS resin and shows relation with **.

[Drawing 5] It is the graph which shows the relation between the addition of PPS resin, and the tensile strength (ordinary temperature, 200 degrees C) of a soft magnetism Plastic solid.

[Drawing 6] It is the graph which shows the relation between the addition of PPS resin, and the tensile strength (200 degrees C) of a soft magnetism Plastic solid.

[Drawing 7] While the relation between the addition of the polyamide system resin in a soft magnetism powder ingredient and PPS resin and the consistency of a test piece is shown, it is the graph which shows the relation of the rate of PPS resin and the consistency of a test piece which are occupied in a resin total amount.

[Drawing 8] It is the graph which shows the relation between the rate of the polyamide system resin occupied in a resin total amount, and PPS resin, and the specific resistance of the test piece after curing.

[Drawing 9] It is the graph which shows the relation between the consistency of the test piece after curing, and the effective permeability of a test piece.

[Drawing 10] It is the graph which shows the relation between the resin total amount in a soft magnetism powder ingredient, and the effective permeability of the test piece after curing.

[Drawing 11] It is the graph which shows the relation between the consistency of the test piece after curing, and the weight iron loss of a test piece.

[Drawing 12] It is a sectional view concerning the example of application.

[Description of Notations]

Among drawing, in mixed powder and 30, shaping metal mold and 40 show a Plastic solid, and 42 shows [20] a soft magnetism Plastic solid.

[Translation done.]

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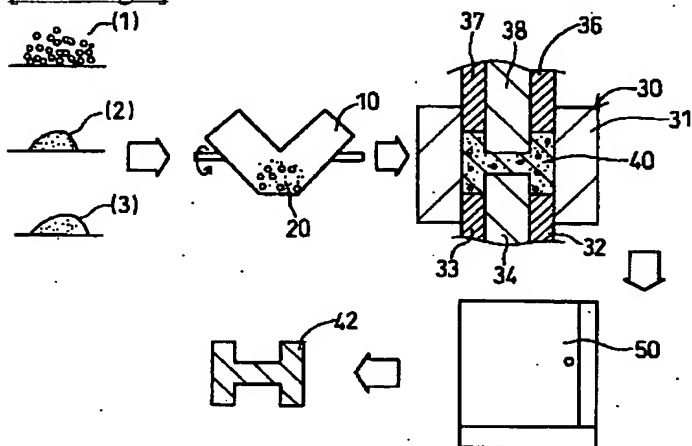
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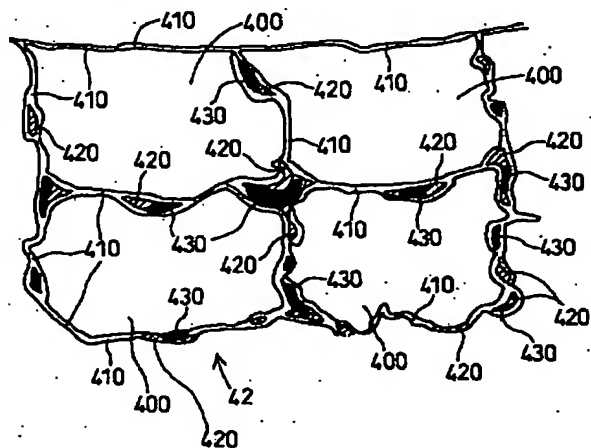
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DRAWINGS

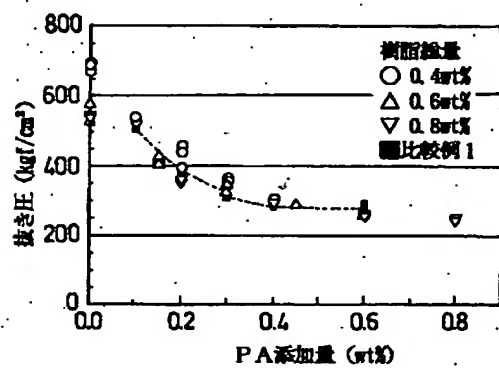
[Drawing 1]



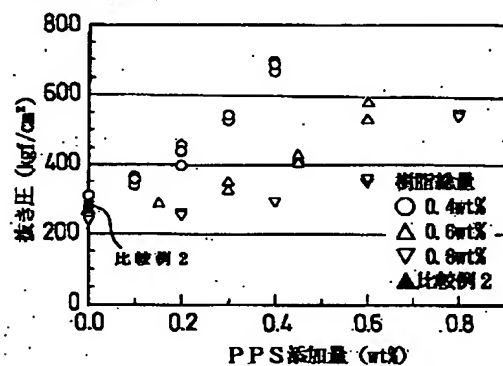
[Drawing 2]



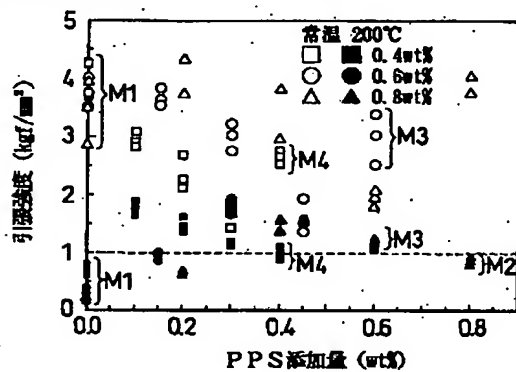
[Drawing 3]



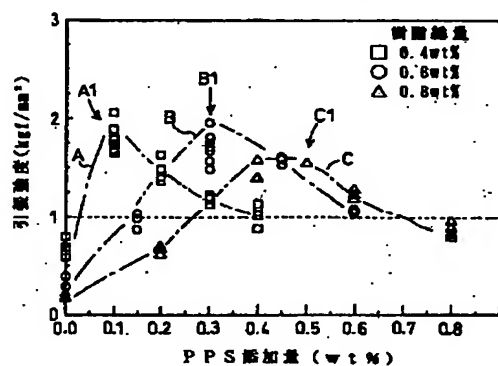
[Drawing 4]



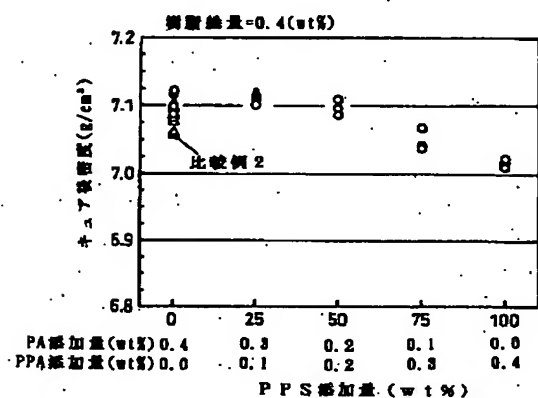
[Drawing 5]



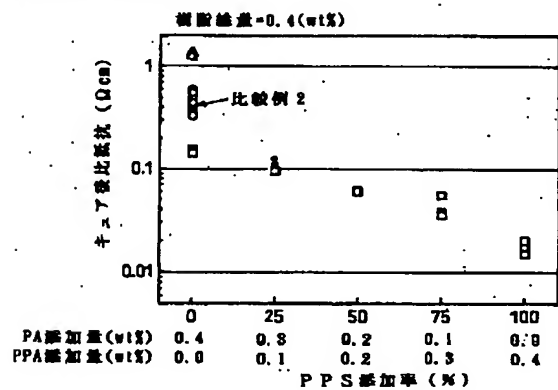
[Drawing 6]



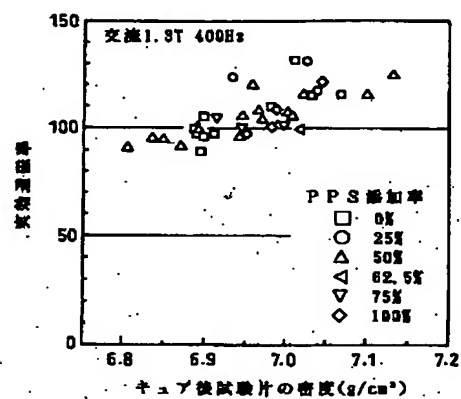
[Drawing 7]



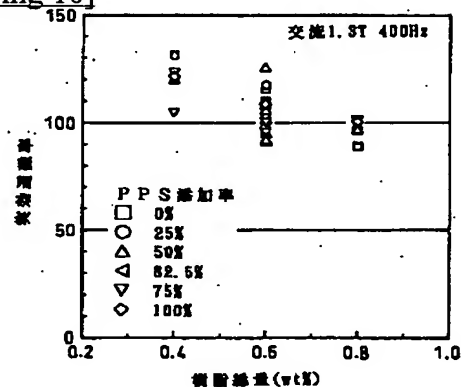
[Drawing 8]



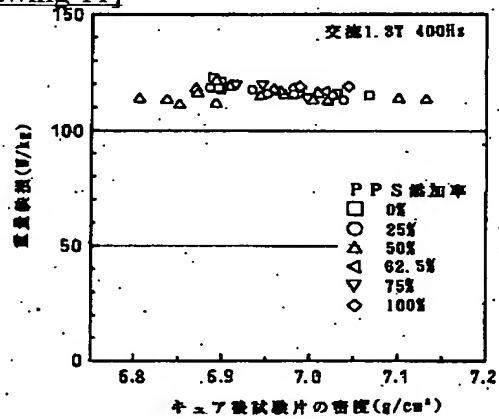
[Drawing 9]



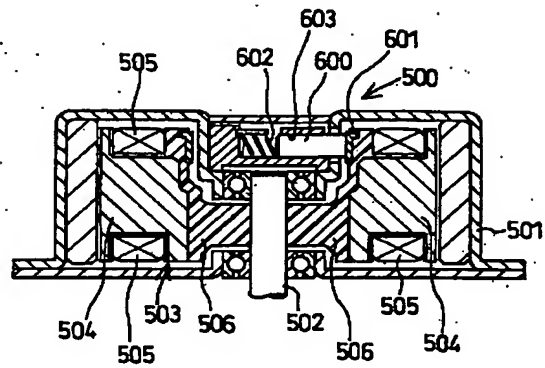
[Drawing 10]



[Drawing 11]



[Drawing 12]



[Translation done.]

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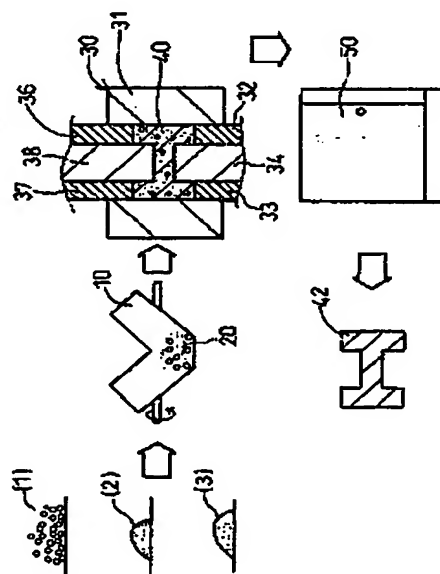
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(54) 【発明の名称】 軟磁性粉末材料、軟磁性成形体及び軟磁性成形体の製造方法

(57) 【要約】

【課題】 高温環境下での強度向上、成型型からの抜き性の向上、磁気特性（透磁率、飽和磁束密度等）と電気特性（比抵抗等）の両方をバランスよく高いレベルで両立させ得るという効果を奏する軟磁性粉末材料、軟磁性成形体、軟磁性成形体の製造方法を提供する。

【解決手段】 軟磁性粉末材料は、電気絶縁性が高い絶縁被膜を有する鉄系粉末粒子（1）と、ポリアミド系の樹脂（2）と、200℃以上の融点をもつ熱可塑性樹脂（3）とを主要成分として混合されている。軟磁性成形体は、上記軟磁性粉末材料を用い、軟磁性粉末材料に対して加圧及び加熱を個別に施して形成されている。



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【特許請求の範囲】

【請求項1】電気絶縁性が高い絶縁被膜を有する鉄系粉末粒子と、ポリアミド系樹脂と、200℃以上の融点をもつ熱可塑性樹脂とを主要成分として混合されていることを特徴とする軟磁性粉末材料。

【請求項2】請求項1において、200℃以上の融点をもつ熱可塑性樹脂はポリフェニレンサルファイド系樹脂であることを特徴とする軟磁性粉末材料。

【請求項3】請求項1または請求項2において、軟磁性粉末材料を100%とし、ポリアミド系樹脂と200℃以上の融点をもつ熱可塑性樹脂との合計を樹脂総量としたとき、樹脂総量は0.1～3.0wt%であることを特徴とする軟磁性粉末材料。

【請求項4】請求項1～請求項3のいずれか一項において、ポリアミド系樹脂と200℃以上の融点をもつ熱可塑性樹脂との合計を樹脂総量とし、樹脂総量を100%としたとき、樹脂総量のうち、ポリアミド系樹脂の占める割合が1～99wt%であり、200℃以上の融点をもつ熱可塑性樹脂の占める割合が1～99wt%であることを特徴とする軟磁性粉末材料。

【請求項5】電気絶縁性が高い絶縁被膜を有する鉄系粉末粒子と、ポリアミド系樹脂と、200℃以上の融点をもつ熱可塑性樹脂とを主要成分として混合されている軟磁性粉末材料を用い、前記軟磁性粉末材料に対して加圧及び加熱を施して形成されていることを特徴とする軟磁性成形体。

【請求項6】電気絶縁性が高い絶縁被膜を有する鉄系粉末粒子と、ポリアミド系樹脂と、200℃以上の融点をもつ熱可塑性樹脂とを主要成分として混合されている軟磁性粉末材料を用い、前記軟磁性粉末材料に対して加圧して圧粉体を形成する第1工程と、前記圧粉体を加熱する第2工程とを順に実施することを特徴とする軟磁性成形体の製造方法。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明は軟磁性粉末材料、軟磁性成形体及び軟磁性成形体の製造方法に関する。本発明は高温環境で使用される軟磁性成形体の製造に資する。

【0002】

【従来の技術】近年、モータコア（ロータコア、ステータコア等）に代表される磁路形成部材の材料として、粉末状の軟磁性材料（主として高純度鉄粉）に樹脂粉末を混ぜた軟磁性粉末材料を用いる技術が着目されている。この軟磁性粉末材料に加圧及び加熱を施すことにより軟磁性成形体を形成する。樹脂粉末は、鉄系粉末粒子を結合させるバインダとしての機能、鉄系粉末粒子間の電気絶縁を図る機能を有する。鉄系粉末粒子間の電気絶縁を図れば、交番磁場が軟磁性成形体に作用するとき、電気

特性（比抵抗等）が良好となり、軟磁性成形体における渦電流損を低減させることができる利点が得られる。

【0003】上記した軟磁性粉末材料を成形型で成形するがゆえのメリットとしては、

A 材料歩留りが非常に良い—低コスト化が可能
B 鋼板を積層させる方式に比較して軟磁性成形体の形状自由度が高い—軟磁性成形体の小型、低コスト化が可能

C 工程短縮が可能—低コスト化が可能

10 D 鋼板を積層させる方式に比較してリサイクル性が高い—地球環境保護、資源有効活用等が挙げられる。

【0004】

【発明が解決しようとする課題】しかしながら、上記した軟磁性粉末材料を成形するがゆえのデメリットとして、

A 軟磁性粉末材料を成形した軟磁性成形体の強度確保（特に高温環境下）が容易ではない。軟磁性粉末材料に樹脂成分が含まれているためである。

20 【0005】イ 軟磁性粉末材料を成形した軟磁性成形体を成形型から容易に取出すための工夫が必要である。軟磁性粉末材料に含まれている樹脂成分が加熱の際に成形型のキャビティ型面に付着するためである。

【0006】ウ 樹脂粉末が軟磁性粉末材料に添加されていると、軟磁性素材としての電気特性（比抵抗等）が向上するものの、樹脂は透磁性に乏しいため、軟磁性成形体の磁気特性（透磁率、飽和磁束密度等）が低下する。そこで電気特性と磁気特性との両方をバランスよく高いレベルで両立させなければならない、といった課題がある。

30 【0007】特にAで示したように、高温環境下での低強度がネックとなり、モータコア等のように強度が要請される用途への採用は難しく、実施された例がない。

【0008】また、イについては、成形型のキャビティ型面の潤滑、あるいは、軟磁性粉末材料自体に潤滑剤を混ぜ込むことで対応可能ではある。しかしながらこの場合には、潤滑剤を添加したり塗布したりするため、コスト、生産性、軟磁性成形体の強度に問題がある。

40 【0009】そこで、樹脂粉末を混ぜた軟磁性粉末材料を採用するためには、上記A、イ、ウの課題を解決しなければならない。

【0010】本発明は上記した実情に鑑みてなされたものであり、高温環境下での強度向上、成形型からの抜き性の向上、磁気特性（透磁率、飽和磁束密度等）と電気特性（比抵抗等）との両方をバランスよく高いレベルで両立させ得るといった効果を奏する軟磁性粉末材料、軟磁性成形体、軟磁性成形体の製造方法を提供することを課題とする。

【0011】

50 【課題を解決するための手段】本発明に係る軟磁性粉末材料は、電気絶縁性が高い絶縁被膜を有する鉄系粉末粒

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子と、ポリアミド系樹脂と、200℃以上の融点をもつ熱可塑性樹脂とを主要成分として混合されていることを特徴とするものである。

【0012】本発明に係る軟磁性成形体は、電気絶縁性が高い絶縁被膜を有する鉄系粉末粒子と、ポリアミド系樹脂と、200℃以上の融点をもつ熱可塑性樹脂とを主要成分として混合されている軟磁性粉末材料を用い、軟磁性粉末材料に対して加圧及び加熱を施して形成されていることを特徴とするものである。

【0013】本発明に係る軟磁性成形体の製造方法は、電気絶縁性が高い絶縁被膜を有する鉄系粉末粒子と、ポリアミド系樹脂と、200℃以上の融点をもつ熱可塑性樹脂とを主要成分として混合されている軟磁性粉末材料を用い、軟磁性粉末材料に対して加圧して圧粉体を形成する第1工程と、圧粉体を加熱する第2工程とを順に実施することを特徴とするものである。

【0014】軟磁性粉末材料は潤滑性が良好なポリアミド系樹脂を含むため、成形後に成形型からの抜き性が確保される。軟磁性粉末材料はポリフェニレンサルファイドに代表される200℃以上の融点をもつ熱可塑性樹脂を含むため、高温環境下での強度が確保される。更に磁気特性（透磁率、飽和磁束密度等）と電気特性（比抵抗等）の両方をバランスよく高いレベルで両立させ得る。

【0015】

【発明の実施の形態】・鉄系粉末粒子は軟磁性成形体の磁気特性（透磁率、飽和磁束密度等）を確保するためのものである。鉄系粉末粒子の平均粒径としては、圧縮成形性を損なわない範囲で大きいことが磁気特性の確保の面からは好ましい。鉄系粉末粒子の平均粒径としては、30～2000μm、70～1000μm、なかでも70～500μm、100～350μmを採用できるが、これらに限定されるものではない。鉄系粉末粒子としては、磁気特性を確保する点からは、鉄の純度が高いものを採用でき、鉄を90wt%、95wt%以上含むものが好ましい。場合によっては鉄系粉末粒子としては、Fe-Si系、Fe-Co系を採用することもできる。鉄系粉末粒子としては、非球状であり、不規則な凹または凸部分を有する不定形等の異形状のものを採用できる。この場合、鉄系粉末粒子の不規則な凹または凸部分が樹脂成分をホールドすることを期待できる。鉄系粉末粒子の製造方法としては、溶湯粉化法（水アトマイズ法、ガスアトマイズ法等）、還元法（ガス還元法等）、機械的粉砕法等を採用できる。ガスアトマイズ法では例えば窒素やアルゴンガス等の不活性ガス、空気を採用できる。

【0016】・鉄系粉末粒子とポリアミド系樹脂と200℃以上の融点をもつ熱可塑性樹脂（以下第2熱可塑性樹脂ともいう）とを混合して混合粉末とした場合、鉄系粉末粒子が球形であれば、樹脂成分と鉄系粉末粒子とは比重差が大きいため、混合する際に比重差により、樹脂成分と鉄系粉末粒子との比重差に起因して分離し、均

一混合性が損なわれるおそれがある。この点、鉄系粉末粒子が不規則な凹または凸部分を有する異形状であれば、ポリアミド系樹脂と第2熱可塑性樹脂と鉄系粉末粒子とを混合する際に、鉄系粉末粒子に樹脂粉末をホールドさせる効果を期待できる。この結果、混合粉末を形成する際に樹脂成分と鉄系粉末粒子との比重差に起因する分離を抑えるのに貢献でき、混合粉末における均一分散性を確保するのに有利となる。この意味においても、鉄系粉末粒子の平均粒径よりも、ポリアミド系樹脂の平均粒径、第2熱可塑性樹脂の平均粒径は小さい方が好ましい。

【0017】・鉄系粉末粒子の表面に電気絶縁性が高い絶縁被膜が形成されている。絶縁被膜は、軟磁性粉末材料の比抵抗を高め、軟磁性成形体に交番磁場が作用するとき交番磁場に起因して軟磁性成形体に生じる渦電流ループを小さくし、渦電流損を小さくさせるためのものである。従って絶縁被膜は電気絶縁性が高いものが好ましい。絶縁被膜としては鉄系粉末粒子の表面の全域の1/2以上、殊に2/3以上に被覆されていることが好ましい。絶縁被膜としては鉄系粉末粒子の表面のほぼ全域に被覆されていることが好ましい。

【0018】・絶縁被膜としては、りん酸化成処理で形成されたりん酸系被膜を例示できる。りん酸系被膜としては、公知のりん酸系被膜を採用でき、りん酸成分とはう酸成分とマグネシア成分とを有するりん酸系の絶縁被膜を例示できる。この場合には、りん酸とほう酸とマグネシアとを有するりん酸系処理液を用い、りん酸系処理液と鉄系粉末粒子の表面とを接触させる工程と、その後乾燥させる工程とにより、りん酸系の絶縁被膜を鉄系粉末粒子の表面に形成することができる。更にはりん酸鉄系の絶縁被膜、りん酸亜鉛系の絶縁被膜、りん酸マンガンの絶縁被膜等を採用しても良い。絶縁被膜の厚みとしては適宜選択できるものの、比抵抗の確保、透磁率の確保等を考慮すると、5～5000nmを採用でき、5～1000nm、5～500nmを採用できるが、これらに限定されるものではない。絶縁被膜の厚みが薄過ぎると、透磁率等の磁気特性が向上するものの、比抵抗が低下し、軟磁性成形体の渦電流損が大きくなり易い。一方、絶縁被膜の厚みが厚過ぎると、比抵抗が確保されて渦電流損を抑え得るものの、透磁率等の磁気特性が低下する。これらの事情を考慮して絶縁被膜の厚みを決定する。

【0019】・ポリアミド（PA）系樹脂は、分子構造にアミド基を有するものであり、融点が比較的低い熱可塑性樹脂であり、潤滑性に優れている。ポリアミド系樹脂としてはPA6、PA66、PA11、PA12、PA46が挙げられ、更にこれらの少なくとも2種を含む共重合体が挙げられる。ポリアミド系樹脂は、一般的には、融点が100～200℃、130～180℃のものを採用できる。

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【0020】・第2熱可塑性樹脂としては、250℃以上の融点をもつ熱可塑性樹脂、260℃以上の融点をもつ熱可塑性樹脂、あるいは、270℃以上の融点をもつ熱可塑性樹脂を採用できる。第2熱可塑性樹脂としては、ポリアミド系樹脂よりも融点が高いものを採用できる。このような第2熱可塑性樹脂として、ポリフェニレンサルファイド（以下PPSともいう）は、融点が高く耐熱性に優れた結晶性を有する熱可塑性材料であり、高温領域下においても良好な耐熱性、電気絶縁性を有する。ポリフェニレンサルファイドは、直鎖型でも、架橋型でも良い。

【0021】・鉄系粉末粒子の接合強度を確保するためには、一般的には、樹脂成分を介在させるよりも、鉄系粉末粒子の絶縁被膜同士を直接接合した方が良い。但しこの場合には樹脂成分が存在しないため、成型型からの抜き性が充分ではなく、型抜きの際に成型体が損傷したり、生産性が低下したりする。第2熱可塑性樹脂がポリアミド系樹脂よりも融点が高いときには、第2熱可塑性樹脂はポリアミド系樹脂よりも溶融しにくい。加熱時または使用時においてポリアミド系樹脂が鉄系粉末粒子の境界域において過剰流動することを第2熱可塑性樹脂が止める作用を期待でき、従って、ポリアミド系樹脂が鉄系粉末粒子の境界域において過剰流動せず、故にポリアミド系樹脂が鉄系粉末粒子の絶縁被膜を過剰に覆ってしまうことを抑え得る。

【0022】軟磁性粉末材料において、ポリアミド系樹脂、第2熱可塑性樹脂の形態としては、粉末状であることが好ましい。上記したポリアミド系樹脂、第2熱可塑性樹脂としては、樹脂粉末の平均粒径が大きすぎると、高温強度の確保の面において不利であると共に、磁気特性（透磁率、飽和磁束密度等）と電気特性（比抵抗等）の両方をバランスよく高いレベルで両立させ得る面においても不利である。ポリアミド系樹脂、第2熱可塑性樹脂は、鉄系粉末粒子よりも粒径が小さい方が好ましい。上記したポリアミド系樹脂、第2熱可塑性樹脂としては、望ましくは200μm以下、さらに望ましくは100μm以下、さらに望ましくは50μm以下とすることができ、場合によっては10μm以下としても良い。殊に、ポリアミド系樹脂、第2熱可塑性樹脂としては、望ましくは200μm以下、さらに望ましくは100μm以下、さらに望ましくは50μm以下のものがそれぞれの樹脂のうち80wt%を占めるものを採用できる。ポリアミド系樹脂の平均粒径をD1とし、第2熱可塑性樹脂の平均粒径をD2としたとき、D1=D2、D1≠D2でも良いし、D1<D2、D1>D2でも良い。この場合、鉄系粉末粒子の平均粒径は、樹脂粉末の平均粒径よりも大きい。

【0023】・軟磁性粉末材料に占める樹脂総量が増加すると、鉄系粉末粒子の割合が相対的に低下し、磁気特

性（透磁率、飽和磁束密度等）が低下すると共に、高温強度も低下する。樹脂総量が減少すると、鉄系粉末粒子の割合が相対的に高くなるため磁気特性が向上するものの、鉄系粉末粒子を接合させるバインダとしての機能が低下すると共に、ポリアミド系樹脂が相対的に減少するため、成型型に対する潤滑性が低下する。上記した点を考慮し、軟磁性粉末材料を100%としたとき、ポリアミド系樹脂と第2熱可塑性樹脂との樹脂総量としては、望ましくは3wt%以下、さらに望ましくは1wt%以下、さらに望ましくは0.8wt%、0.7wt%以下にできる。例えば樹脂総量としては0.1~3.0wt%、0.1~2.0wt%、0.1~1.0wt%とすることができる。ただしこれらに限定されるものではない。

【0024】・ポリアミド系樹脂と第2熱可塑性樹脂との合計を樹脂総量を100%としたとき、樹脂総量のうちポリアミド系樹脂が占める割合としては1~99wt%、殊に20~80wt%とすることができ、樹脂総量のうち第2熱可塑性樹脂が占める割合としては1~99wt%、殊に20~80wt%とすることができる。第2熱可塑性樹脂は軟磁性成型体の高温強度を確保するのに有利であるが、第2熱可塑性樹脂を多めに添加すると、ポリアミド系樹脂の添加量が相対的に減少するため、潤滑性が不足し、成型型の成形キャビティから成型体を抜く際の抜き圧が増加する不具合がある。第2熱可塑性樹脂を少なめに添加すると、ポリアミド系樹脂の添加量が相対的に増加するため、潤滑性が向上し、成型型の成形キャビティから成型体を抜く際の抜き圧を低減させ得るものの、軟磁性成型体の高温強度が低下する不具合がある。そこでポリアミド系樹脂の添加量、第2熱可塑性樹脂の添加量としては、上記した割合が好ましい。

【0025】・上記した軟磁性成型体は、上記した軟磁性粉末材料を用い、軟磁性粉末材料に対して加圧及び加熱を施して形成されている。加圧及び加熱は個別に行っても良いし、同時に行っても良い。この場合、軟磁性粉末材料を金型等の成型型にて圧縮成型して圧粉体を形成する第1工程、その後、圧粉体を加熱してキュアリングする第2工程とを実施することにより形成できる。成型型を用いる第1工程は常温領域で行うことが好ましい。常温領域で軟磁性粉末材料を加圧すれば、樹脂成分が成型型のキャビティ型面に付着することが抑えられ、圧粉体を成型型のキャビティ型面から良好に型抜きすることができる。第1工程での加圧力としては、鉄系粉末粒子等の種類、軟磁性成型体の形状に応じて適宜選択できるものの、50MPa~1000MPa（1kgf/cm²~40.1MPaとすると、約500kgf/cm²~約10000kgf/cm²）を採用できる。殊に100MPa~800MPa（約1000kgf/cm²~約8000kgf/cm²）を採用できる。仮に第1工程で軟磁性粉末材料が加圧されると共に加熱されると、軟

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磁性粉末材料に含まれている樹脂が成形金型等の成型型のキャビティ型面に接着することがあるため、成型型からの型抜き性が容易でなくなり、生産性が低下する。

【0026】第1工程での加圧時間としては、0.1～20秒、0.5～10秒、0.5～5秒を採用できる。生産性の向上のためには加圧時間は短い方が好ましい。但し加圧力及び加圧時間としては上記した値に限定されるものではない。第1工程の雰囲気としては大気雰囲気を採用できるが、場合によっては不活性ガス雰囲気としても良い。第2工程では、ポリアミド系樹脂と第2熱可塑性樹脂の双方とを溶かし、鉄系粉末粒子に対する接着性を高めることが好ましい。したがって第2工程は、圧粉体を加熱した状態で行うことができる。ポリアミド系樹脂は融点が相対的に低いため、加熱時に、鉄系粉末粒子同士の粒界において流動し易いものと推察される。このようにポリアミド系樹脂が流動して鉄系粉末粒子の表面に片状または膜状に存在すれば、ポリアミド系樹脂が粒状である場合に比較し、りん酸系被膜等のように絶縁被膜として効果的に機能し易く、軟磁性粉末材料及び軟磁性成形体の比抵抗を高めて渦電流損を抑えるのに有利であるものと推察される。但し、ポリアミド系樹脂が鉄系粉末粒子同士の粒界において過剰流動すると、軟磁性成形体の磁気特性が低下するおそれがあり、更に鉄系粉末粒子同士の接着強度を低下させるおそれがある。このため軟磁性成形体の磁気特性を確保する意味では、また軟磁性成形体の強度を確保する意味では、ポリアミド系樹脂の過剰流動は好ましくない。

【0027】加熱温度が高すぎると、軟磁性粉末材料に含まれている樹脂が劣化したり、絶縁被膜が劣化するおそれがある。加熱温度が低すぎると、軟磁性粉末材料に含まれている樹脂による接着力が向上しない。このような点を考慮し、加熱温度としては450℃以下、さらに望ましくは350℃以下を採用できる。従って第2工程では450℃以下、さらに望ましくは350℃以下を採用できる。第2工程での下限値温度としては、第2熱可塑性樹脂の融点を越えることが好ましく、従って第2熱可塑性樹脂の種類に応じて250℃以上、270℃以上、280℃以上、290℃以上のいずれかとすることができる。故に軟磁性粉末材料を加熱するときの加熱温度としては、250～450℃、殊に270～350℃を例示できる。第2工程の雰囲気としては大気雰囲気を採用できるが、場合によっては不活性ガス雰囲気としても良い。一般的には第2工程は金型等の成型型内で行うものではなく、放置した状態（非拘束状態）で行うため、成型金型等の成型型に対する型抜き性を考慮する必要が特にない。場合によっては、温度調整された成型金型等の成型型にて、軟磁性粉末材料の圧粉成形と同時に加熱してキュアリングを行っても良い。

【0028】軟磁性成形体としては、モータ、電磁バルブ等に代表される電磁アクチュエータに使用される磁

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路形成部材に用いることができる。モータに適用される磁路形成部材としてはロータコア、ステータコア等を採用できる。モータとしては、アンチロックブレーキシステム用モータ、パワーステアリング用モータ、ワイパーモータ、ウィンドレギュレータ用モータ、サンルーフ用モータ等の各種モータが挙げられる。軟磁性成形体としては、トルクセンサ、変位センサ等の各種センサで使用される磁路形成部材が挙げられる。本発明に係る軟磁性粉末材料で成形された軟磁性成形体は、車等のエンジンルームのように高温環境下で使用される軟磁性成形体に適するが、成型時の成型キャビティからの型抜き性が良好である効果も奏することから、高温環境で使用される軟磁性成形体のみに限定されるものではない。

【0029】

【実施例】以下、本発明の実施例を具体的に説明する。

【0030】図1は製造過程を模式的に示す。出発原料として(1)(2)(3)を用いた。

(1)金属粉末として、ヘガネス社のSomaLOY550を使用した。この金属粉末は、高純度の鉄系粉末粒子（鉄粉、Fe-0.01wt% C以下、H₂ loss 0.08wt%、粒径：約20～200μm）の表面に、りん酸化成被膜処理によりりん酸系被膜が被覆されている。りん酸系被膜は電気絶縁性が高い絶縁被膜として機能するものであり、鉄系粉末粒子のほぼ全表面に被覆されている。鉄系粉末粒子は軟磁性特性を確保する。りん酸被膜は電気絶縁抵抗が高く、交番磁場が作用したときにおける軟磁性成形体の渦電流損を低減させるのに有利である。

(2)ポリアミド系樹脂（平均粒径：約10μm）を用いた。この平均粒径は粒度分布における最頻度値を意味する。ポリアミド系樹脂は熱可塑性樹脂であり、潤滑性が良好であり、粉末潤滑剤として機能できる。ポリアミド系樹脂は鉄系粉末粒子との常温領域における接着強度を確保するにも貢献できる。本実施例で用いたポリアミド系樹脂の融点は約140℃である。

(3)PPS樹脂（平均粒径：約18μm）を用いた。この平均粒径は粒度分布における最頻度値を意味する。PPS樹脂は、第2熱可塑性樹脂として機能するものであり、鉄系粉末粒子との接着強度、殊に高温環境下での接着強度を高めるのに貢献できる。PPS樹脂の融点は約280℃である。

【0031】そして図1に示すように、(1)の鉄系粉末と(2)(3)の粉末状の樹脂とを所定量秤量した状態で、混合機10を回転駆動させることにより三者を60分間混合し、混合粉末20を形成した。鉄系粉末粒子とポリアミド系樹脂とPPS樹脂とが混合された状態の混合粉末20である軟磁性粉末材料を用い、第1工程を実施した。即ち、軟磁性粉末材料を成型金型である成型金型30のキャビティ内に供給し、室温にて成型金型30で加圧成形し、圧粉体である成形体40を得た。成形

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金型30は、筒形状のダイス型31と、ダイス型31に嵌合された下型32と、ダイス型31に嵌合された上型36とを有する。下型32は筒形状の外側下型33と内側下型34とを有する。上型36は筒形状の外側上型37と内側上型38とを有する。

【0032】本実施例によれば、成形金型30のキャビティ内の軟磁性粉末材料である混合粉末20を加圧するものの、加圧するときの温度は室温であるため、混合粉末20の樹脂成分が溶融せず、樹脂成分が成形金型30のキャビティ型面に付着する問題を解消するのに有利となる。軟磁性粉末材料である混合粉末20を加圧する加圧条件としては、加圧力を600MPa（約6000kgf/cm²）とし、加圧時間は約1秒程度とした。

【0033】その後、成形金型30のキャビティから取り出された圧粉体である成形体40を熱処理炉50により、大気中において加熱して成形体40に対してキュアリングを行ない、第2工程を実施し、軟磁性成形体42を得た。第2工程では、加熱によりポリアミド系樹脂とPPS樹脂とが溶融し、鉄系粉末粒子を結合させるバインダとしての機能を高めることになる。第2工程における加熱条件としては、加熱温度を300℃、加熱時間を60分間とした。なお第2工程においては加圧は特に施されておらず、成形体40は非拘束状態である。従って第2工程で成形体40や軟磁性成形体42が相手型に接することを選択することができる。

【0034】図2はキュアリング後の軟磁性成形体42の内部をEPMAで観察した状態を撮写したものである。この観察した軟磁性成形体42では、軟磁性粉末材料を100%としたとき、重量比でポリアミド系樹脂が0.3%であり、PPS樹脂が0.3%であった。図2に示すように、薄層状のりん酸系被膜410は鉄系粉末粒子400の表面の全域に積層されていた。そしてりん酸系被膜410が積層された鉄系粉末粒子400が互いに固結されていた。この場合、りん酸系被膜410同士が接合している部分が多かった。りん酸系被膜410が積層された鉄系粉末粒子400の境界域にポリアミド系樹脂の片状の相420（ハッチング線を示す領域）、PPS樹脂の片状の相430（黒色塗り潰し領域）が存在している。図2によれば、ポリアミド系樹脂の片状の相420、PPS樹脂の片状の相430とはあまり相溶せず、互いに独立して存在していることがうかがえる。図2によれば、鉄系粉末粒子400の凹み部分にポリアミド系樹脂の片状の相420、PPS樹脂の片状の相430が存在していることがうかがえる。更に図2によれば、ポリアミド系樹脂の相420の過剰流動がPPS樹脂の相430で止められている形態がうかがえる。ポリアミド系樹脂の相420の過剰流動を止めるには、PPS樹脂の粒径がポリアミド系樹脂の粒径よりも大きいことが効果的であると推察される。

【0035】本発明者らが行った試験によれば、同一条

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件で製造しつつも樹脂を全く添加しなかった試験片では、成形金型30からの型抜き性が悪いもののキュアリング後の強度が高いことから、りん酸系被膜同士の接合強度は高いことが判明している。上記したようにポリアミド系樹脂の相420の過剰流動がPPS樹脂の相430で止められていれば、鉄系粉末粒子400の接合強度が高いりん酸系被膜同士の接合が確保され、軟磁性成形体42の強度を確保するのに貢献できるものと推察される。

【0036】上記実施例の中で、まず、問題となるのが、成形金型30のキャビティから成形体40を取り出す際の取り出しやすさ（抜き圧力の大小）である。この場合、成形体40の抜き圧力を小さくする必要がある。一般的には成形金型30のキャビティ型面に潤滑剤を塗布したり、軟磁性粉末材料と潤滑剤とを混ぜ合わせて対応することになる。しかしこの手段ではコスト、生産性に問題がある。またキュアリング後の軟磁性成形体42としての性能、強度が低下してしまう不具合がある。これに対して、本実施例のようにバインダ機能の他に潤滑剤機能を有するポリアミド系樹脂を軟磁性粉末材料に所定量入れ込むことにより、バインダとしての機能はもちろんだ。成形体40を成形金型30のキャビティから抜くときの抜き圧力を低減させるのに大きな効果を得ることができる。

【0037】しかしながら、軟磁性粉末材料に樹脂としてポリアミド系樹脂のみを混ぜた場合には、エンジンルームなどで使用されるモータ等のように高温環境下（例えば180～260℃）で使用されるとき、軟磁性成形体42の強度が著しく低下してしまう不具合がある。これは使用環境温度がポリアミド系樹脂の融点を越えているためで、ポリアミド系樹脂による接合強度は高温環境下ではあまり期待できない。この問題を解決するために必要なものがPPS樹脂である。PPS樹脂の融点は、約270～290℃であり、上記した高温環境温度より高い。したがってPPS樹脂は上記した高温環境温度においても溶融しないため、高温環境で軟磁性成形体42を使用するとき、PPS樹脂のもつ接着力が接合強度として発揮される。また高温環境温度において溶融状態にあるポリアミド系樹脂が鉄系粉末粒子400の表面に過剰に流動するのを防止するための流動バリア的な機能を待っており、高温環境下での強度向上に貢献している。

【0038】（評価）軟磁性粉末材料から軟磁性成形体42である試験片を作製し、各種試験を行った。試験片は、基本的には上記した条件に基づいて形成されている。そして、軟磁性粉末材料に配合されているポリアミド系樹脂及びPPS樹脂の添加量と各特性値との関係を試験した。図面中、ポリアミド系樹脂をPAとも記し、PPS樹脂をPPSとも記す。

【0039】まず、第1工程を実施した後における成形金型30からの圧粉体である成形体40の取り出しやす

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さについて、図3及び図4を参照して説明する。図3の横軸はポリアミド系樹脂の添加量を示す。図3の縦軸は成形金型30からの圧粉体である成形体で形成されている試験片を取り出す際の抜き圧を示す。図3において○は樹脂総量が0.4wt%の場合を示し、△は樹脂総量が0.6wt%の場合を示し、▽は樹脂総量が0.8wt%の場合を示す。樹脂総量が0.4wt%とは、混合粉末全体を100%としたとき、樹脂総量が0.4wt%を占めると共に、りん酸系被膜が積層されている鉄系粉末粒子が99.6wt%占めることを意味する。樹脂総量が○であり0.4wt%である場合において、ポリ

アミド系樹脂の添加量が0.1wt%であるときには、ポリアミド系樹脂が0.1wt%で、PPS樹脂が0.3wt%であることを示す。また、樹脂総量が△であり0.6wt%である場合において、ポリアミド系樹脂の添加量が0.3wt%であるときには、ポリアミド系樹脂が0.3wt%で、PPS樹脂が0.3wt%であることを示す。■は比較例1を示す。比較例1は、りん酸系被膜が積層されている鉄系粉末粒子（実施例と同じ鉄系粉末粒子）にポリアミド系樹脂を添加するものの、PPS樹脂を添加していないものであり、ポリアミド系樹脂の量を変化させたものである。図3に示すように、ポリアミド系樹脂の添加量が増加すれば、試験片の抜き圧は低減しており、ポリアミド系樹脂は抜き圧の低減に大きく寄与していることがわかる。

【0040】図4の横軸はPPS樹脂の添加量を示す。図4の縦軸は成形金型30からの圧粉体である成形体で形成されている試験片を取り出す際の抜き圧を示す。図4に示す試験によれば、比較例2はりん酸系被膜が積層されている鉄系粉末粒子（実施例と同じ鉄系粉末粒子）にポリアミド系樹脂0.6wt%添加しているものの、PPS樹脂を含まない。図4に示すように、PPS樹脂の添加量は、成形体である試験片の抜き圧にはほとんど影響しない。したがって、試験片の抜き圧だけを考えれば、ポリアミド系樹脂をより多目に添加すればよいことになる。

【0041】次に、キュアリング後の軟磁性成形体である試験片の引張強度について図5、図6を参照して説明する。図5の横軸は、軟磁性粉末材料を100%としたときPPS樹脂の添加量を示す。図5の縦軸は常温引張強度、200℃における引張強度を示す。引張強度は軟磁性粉末材料を上記加圧条件で圧縮した圧粉体を上記加熱条件で加熱してキュアリング（300℃×1時間）した軟磁性成形体で形成されている試験片の引張強度を示す。引張強度試験としては、JIS規格2-2241の「金属材料引張試験方法」に基づいて行った。図5から理解できるように、ポリアミド系樹脂のみが添加されている試験片群M1、つまりPPS樹脂が添加されていない試験片群M1では、室温での引張強度は高い値を示すものの、高温環境下（200℃）での強度は1kgf/

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mm²（≒9.8MPa）をなかなか越えることができず、低い値となっている。またPPS樹脂のみが添加されている試験片群M2、M3、M4についても、ポリアミド系樹脂のみが添加されている場合ではほどではないが、高温環境下での強度は充分ではない。

【0042】しかしながら図5から理解できるように、ポリアミド系樹脂とPPS樹脂の両方を併せて添加した軟磁性粉末材料を用いることで、高温環境下での強度が向上する傾向が見られる。これらの試験結果により、高温環境下での強度を確保するには、ポリアミド系樹脂とPPS樹脂の両方を併せて添加することが重要であることがわかる。

【0043】なお、鉄粉末粒子にりん酸系被膜を積層した軟磁性粉末材料（ポリアミド系樹脂及びPPS樹脂の両方を含まない）で形成した軟磁性成形体については、室温における引張強度は約2.6kgf/mm²程度であり、200℃における引張強度は約2.6kgf/mm²程度であった。

【0044】また図6の横軸はPPS樹脂の添加量を示し、図6の縦軸は200℃における軟磁性成形体である試験片の引張強度を示す。図6の特性線Aのピーク領域A1で示すように樹脂総量が0.4wt%（□）のときには、PPS樹脂が0.1%（ポリアミド系樹脂：0.3wt%）の場合、高温引張り強度が高い。図6の特性線Bのピーク領域B1で示すように樹脂総量が0.6wt%（○）のときには、PPS樹脂が0.3%（ポリアミド系樹脂：0.3wt%）の場合、高温引張強度が高い。図6の特性線Cのピーク領域C1で示すように樹脂総量が0.8wt%（△）のときには、PPS樹脂が約0.5%（ポリアミド系樹脂：0.3wt%）の場合、高温引張強度が高い。これを考慮すれば、試験した範囲内では、混合粉末である軟磁性粉末材料を100%としたとき、ポリアミド系樹脂が0.3wt%付近のとき、高い高温引張強度が得られ、良好なる混合比率が存在しているといえる。

【0045】次に、成形体である試験片のキュアリング後の試験片の密度について図7を参照して説明する。図7の横軸は、樹脂総量を100%としたとき、樹脂総量に占めるPPS樹脂の割合を示す。また図7の縦軸は、軟磁性粉末材料を100%としたとき、軟磁性粉末材料におけるポリアミド系樹脂及びPPS樹脂の添加量も示す。図7の縦軸はキュアリング後の試験片の密度を示す。この場合には樹脂総量を0.4wt%、第1工程での加圧力を6000kgf/cm²と（600MPa）とした。図7に示すように、樹脂総量が同一であるとき、樹脂総量に占めるPPSの割合が増加しても、軟磁性成形体である試験片の密度は良好であった。特にPPS樹脂が0.1wt%、0.2wt%、0.3wt%のとき、試験片の密度は良好であった。なお、比較例2は、りん酸系被膜が積層された鉄系粉末粒子を加圧・加

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熱して成形されており、ポリアミド系樹脂を0.6wt%含むものの、PPS樹脂を含まない。

【0046】次に、成形体である試験片のキュアリング後の比抵抗について図8を参照して説明する。図8の横軸は、樹脂総量を100%としたとき、樹脂総量に占めるPPS樹脂の割合(0%、25%、50%、75%、100%の数値をもつ軸で表現される)を示す。また図8の縦軸は、軟磁性粉末材料を100%としたとき、軟磁性粉末材料におけるポリアミド系樹脂及びPPS樹脂の添加量(0.4%、0.3%、0.2%、0.1%の数値をもつ軸で表現される)も示す。図8の縦軸はキュアリング後の成形体である試験片の比抵抗を示す。この試験では、第1工程での加圧力を6000kgf/cm²(600MPa)とした。図8に示すように、樹脂総量が同一であるとき、ポリアミド系樹脂の量が増加するにつれて、比抵抗が増加している。即ちPPS樹脂の量が多くなるにつれて、比抵抗が低下している。図8によれば、ポリアミド系樹脂が0%のとき比抵抗がかなり低下している。このため試験片の比抵抗を高くして渦電流損を抑えるためには、ポリアミド系樹脂の量が多い方が

良いといえる。

【0047】図8の試験結果のようにポリアミド系樹脂の量が増加するにつれて比抵抗が増加する理由としては、ポリアミド系樹脂はPPS樹脂よりも融点が低いため、りん酸系被膜が形成されている鉄系粉末粒子間において加熱の際に流動し易く、PPS樹脂よりも片状または膜状に存在し易いためと推察される。このポリアミド系樹脂は高い電気絶縁性を有するため、鉄系粉末粒子において片状または膜状に存在すれば、電流通路を制限するのにも有利であり、軟磁性成形体である試験片の比抵抗を高めるものと推察される。

【0048】次に実効透磁率について図9及び図10を参照して説明する。図9の横軸はキュアリング後の軟磁性成形体である試験片の密度を示し、図9の縦軸はキュアリング後の軟磁性成形体である試験片の実効透磁率を示す。また樹脂総量は0.4~0.8wt%範囲内とした。この場合、ポリアミド系樹脂とPPS樹脂との合計を100%としたとき、PPS樹脂の割合を0%、25%、50%、62.5%、75%、100%と変化した。実効透磁率を測定するにあたり、トロイダルコイルに400Hzの交番電流を通過し、交番磁場(1.3T)を発生させた状態で測定した。図9に示すように、キュアリング後の軟磁性成形体である試験片の密度は実効透磁率に影響を与えるものの、樹脂総量が変化して、あるいは、ポリアミド系樹脂とPPS樹脂の添加割合が変化して、試験片の密度が多少ばらついたとしても、良好な実効透磁率が得られる。

【0049】図10の横軸は軟磁性粉末材料に占める樹脂総量を示す。図10の縦軸はキュアリング後の軟磁性成形体である試験片の実効透磁率を示す。この場合、ポ

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リアミド系樹脂とPPS樹脂との合計を100%としたとき、PPS樹脂の添加量を0%、25%、50%、62.5%、75%、100%と変化した。図10に示すように、樹脂総量が増加するにつれて試験片の実効透磁率が低下する傾向が見られた。軟磁性の鉄系粉末粒子の割合が低下するためである。このため軟磁性粉末材料を100%としたとき、樹脂総量は1.5wt%未満、殊に1.0wt%未満が好ましいと言える。

【0050】次に実効透磁率について図11を参照して説明する。図11の横軸はキュアリング後の軟磁性成形体である試験片の密度を示し、図11の縦軸は重量鉄損を示す。この場合、樹脂総量を100%としたとき、樹脂総量に占めるPPS樹脂の割合を0%、25%、50%、62.5%、75%、100%に変化した。この試験では、トロイダルコイルに400Hzの交番電流を通過して交番磁場(1.3T)を発生させた状態で測定した。また樹脂総量は0.4~0.8wt%範囲内とした。重量鉄損(w/kg)は、ヒステリシス損と渦電流損の総和である。図11に示すように、ポリアミド系樹脂とPPS樹脂の添加割合が変化して試験片の密度が多少ばらついたとしても、鉄損はあまり変化がない。

【0051】以上説明したように軟磁性成形体における要求特性に合わせて上記ポリアミド系樹脂、PPS樹脂の添加量をコントロールすることで、成形金型等の成形型のキャビティから成形体を取り出してやすくしつつ、磁気特性、電気特性(比抵抗)が良好で、かつ、高温環境下での強度が高い軟磁性粉末成形体を得ることができる。

【0052】(適用例)図12はモータの代表例であるブラシモータ(電磁アクチュエータ)に適用した適用例を示す。ブラシモータ500は、ケース501と、ケース501に回転可能に設けられた作動部としてのシャフト502と、シャフト502に保持された電機子503とを有する。電機子503は、磁路を形成するコア504と、コア504に保持され磁力線を生成する電機子コイル505と、コア504をシャフト502に保持する支持部506とを有する。ブラシ600はブラシ当接部601に対して内側から外側に向かって当接するようにコイルバネ602により付勢された状態でブラシホルダ603に保持されている。シャフト502が回転すると、コア504に遠心力が作用する。このモータは車両のエンジンルーム内等の高温環境下で使用されることがある。このモータが車両で使用される際にはコア504に車両振動も遠心力の他に作用する。

【0053】コア504は磁路ループを形成する磁路形成部材であり、上記した実施例に係る軟磁性成形体で形成されており、高温環境下での強度向上が図られている。高温環境下において遠心力や振動がコア504に作用する状態でコア504が使用されても、コア504の強度は十分に確保される。

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【0054】更にコア504は上記した実施例に係る軟磁性成形体で形成されているため、成形金型等の成形型からの抜き性の向上、磁気特性（透磁率、飽和磁束密度等）と電気特性（比抵抗等）の両方をバランスよく高いレベルで両立させ得るといった効果を奏する。本発明は上記ブラシモータに限らず、他のモータ、更には他の電磁アクチュエータに適用することもできる。

【0055】（その他）その他、本発明方法及び本発明装置は上記した実施例のみに限定されるものではなく、要旨を逸脱しない範囲内で適宜変更して実施できるものである。

【0056】上記した記載から次の技術的思想も把握できる。

（付記項1）車両のエンジンルーム内などの高温環境で用いられる各請求項に係る軟磁性成形体。エンジンルーム内などの高温環境で使用するのに適する。

（付記項2）車両のエンジンルーム内などの高温環境で用いられる各請求項に係る磁路形成部材。エンジンルーム内のような高温環境で使用するのに適する。

（付記項3）電気絶縁性が高い絶縁被膜を有する鉄系粉末粒子とポリアミド系樹脂と200℃以上の融点をもつ熱可塑性樹脂とを主要成分とする軟磁性粉末材料を形成する混合工程と、軟磁性粉末材料に対して加圧して圧粉体を形成する加圧工程（第1工程）と、圧粉体を加熱する加熱工程（第2工程）とを順に実施することを特徴とする軟磁性成形体の製造方法。

（付記項4）ケースと、ケースに回転可能に設けられたシャフトと、シャフトに保持された電極子とを有するモータであり、電極子は、各請求項に係る軟磁性成形体で形成された磁路を形成するコアと、コアに保持された電磁子コイルとを有することを特徴とするモータ。高温環境下での強度向上、成形型からの抜き性の向上、磁気特性（透磁率、飽和磁束密度等）と電気特性（比抵抗等）の両方をバランスよく高いレベルで両立させ得る。

（付記項5）ケースと、ケースに作動可能に設けられた作動部と、磁路を形成するコアとを有する電磁アクチュエータにおいて、コアは、各請求項に係る軟磁性成形体で形成されていることを特徴とする電磁アクチュエータ。高温環境下での強度向上、成形型からの抜き性の向上、磁気特性（透磁率、飽和磁束密度等）と電気特性（比抵抗等）の両方をバランスよく高いレベルで両立させ得る。

（付記項6）電気絶縁性が高い絶縁被膜を有する鉄系粉末粒子と、ポリアミド系樹脂と、200℃以上の融点をもつ熱可塑性樹脂とを主要成分として混合されており、200℃以上の融点をもつ熱可塑性樹脂の平均粒径は、ポリアミド系樹脂の平均粒径よりも大きいことを特徴とする軟磁性粉末材料。

（付記項7）電気絶縁性が高い絶縁被膜を有する鉄系粉末粒子と、ポリアミド系樹脂と、200℃以上の融点を

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もつ熱可塑性樹脂とを主要成分として混合されており、200℃以上の融点をもつ熱可塑性樹脂の平均粒径は、ポリアミド系樹脂の平均粒径よりも大きく、鉄系粉末粒子の平均粒径は、200℃以上の融点をもつ熱可塑性樹脂の平均粒径よりも大きいことを特徴とする軟磁性粉末材料。

【0057】

【発明の効果】以上説明したように本発明によれば、高温環境下での強度向上、成形型からの抜き性の向上、磁気特性（透磁率、飽和磁束密度等）と電気特性（比抵抗等）の両方をバランスよく高いレベルで両立させ得るといった効果を奏する軟磁性粉末材料、軟磁性成形体、軟磁性成形体の製造方法を提供することができる。

【0058】殊に、上記した軟磁性粉末材料を用い、軟磁性粉末材料に対して加圧して圧粉体を形成する第1工程と、圧粉体を加熱する第2工程とを順に実施する製造方法によれば、第1工程において成形型から圧粉体を抜く抜き性が良好に確保され、生産性の向上を図り得ると共に、潤滑剤を成形型のキャビティ型面に塗布したり、潤滑剤を軟磁性粉末材料に混ぜたりすることを低減または回避できるため、軟磁性成形体の高品質化に有利である。

【0059】200℃以上の融点をもつ熱可塑性樹脂がポリフェニレンサルファイド系樹脂である場合には、軟磁性成形体が高温環境下で使用されるとき、軟磁性成形体の強度を確保するのに有利である。更に、軟磁性粉末材料を100%とし、ポリアミド系樹脂と200℃以上の融点をもつ熱可塑性樹脂との合計を樹脂総量としたとき、樹脂総量を0.1～3.0wtとした場合には、鉄系粉末粒子に対して樹脂成分が適切となり、高温環境下での強度向上、成形型からの抜き性の向上、磁気特性（透磁率、飽和磁束密度等）と電気特性（比抵抗等）の両方をバランスよく高いレベルで両立させ得るといった効果を奏するのに有利である。

【図面の簡単な説明】

【図1】製造過程を模式的に示す工程図である。

【図2】軟磁性成形体の内部構造をE PMAで観察した状態を模写した構造図である。

【図3】ポリアミド系樹脂の添加量と抜き圧との関係を示すグラフである。

【図4】PPS樹脂の添加量と抜き圧との関係を示すグラフである。

【図5】PPS樹脂の添加量と軟磁性成形体の引張強度（常温、200℃）との関係を示すグラフである。

【図6】PPS樹脂の添加量と軟磁性成形体の引張強度（200℃）との関係を示すグラフである。

【図7】軟磁性粉末材料におけるポリアミド系樹脂及びPPS樹脂の添加量と試験片の密度との関係を示すと共に、樹脂総量に占めるPPS樹脂の割合と試験片の密度との関係を示すグラフである。

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【図8】樹脂総量に占めるポリアミド系樹脂及びPPS樹脂の割合とキュアリング後の試験片の比抵抗との関係を示すグラフである。

【図9】キュアリング後の試験片の密度と試験片の表効透磁率との関係を示すグラフである。

【図10】軟磁性粉末材料における樹脂総量とキュアリング後の試験片の表効透磁率との関係を示すグラフであ*

*る。

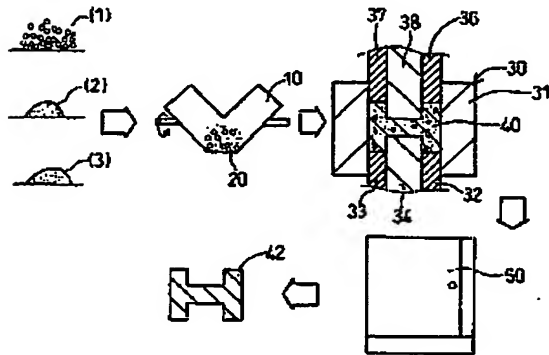
【図11】キュアリング後の試験片の密度と試験片の重量鉄損との関係を示すグラフである。

【図12】適用例に係る断面図である。

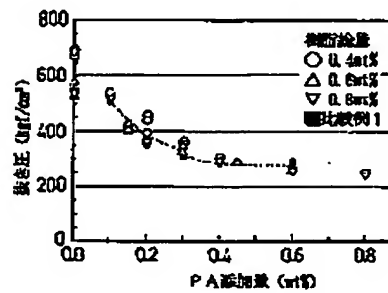
【符号の説明】

図中、20は混合粉末、30は成形金型、40は成形体、42は軟磁性成形体を示す。

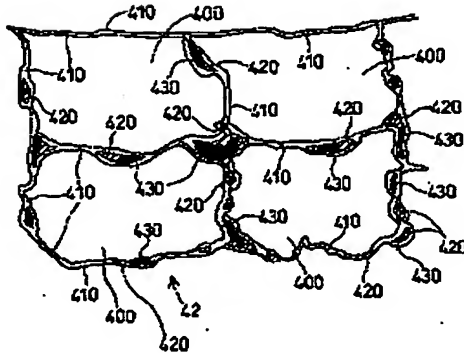
【図1】



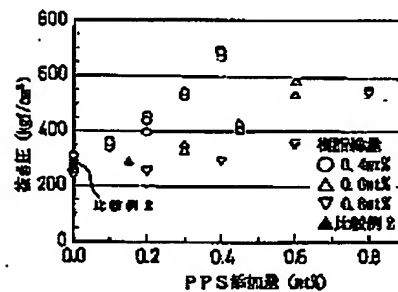
【図3】



【図2】



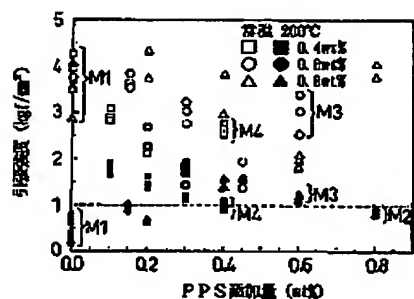
【図4】



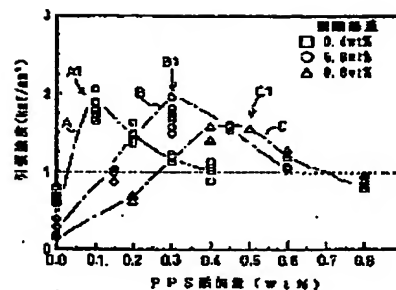
(11)

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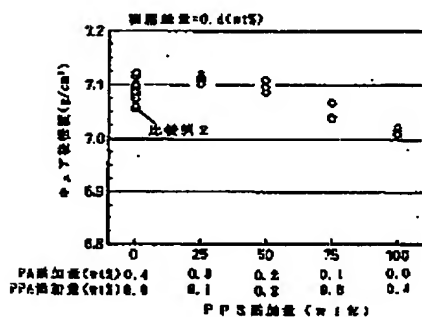
【図5】



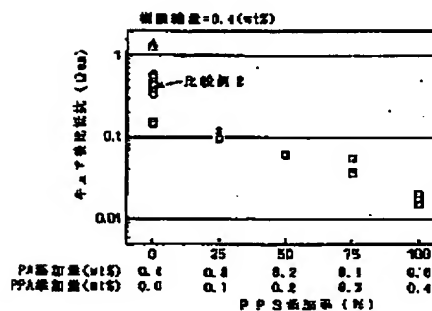
【図6】



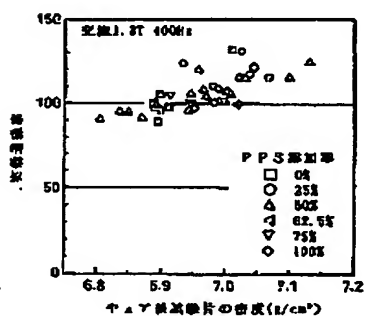
【図7】



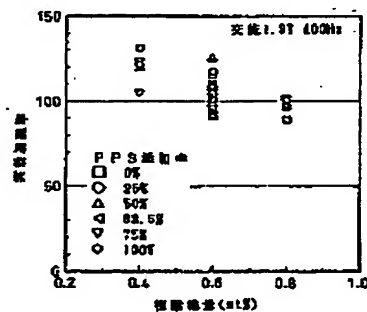
【図8】



【図9】



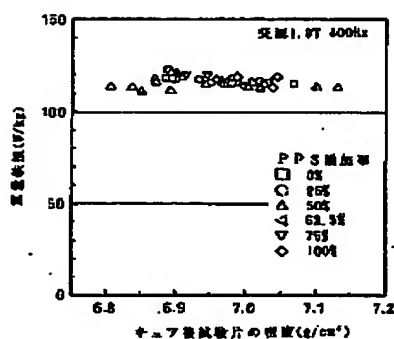
【図10】



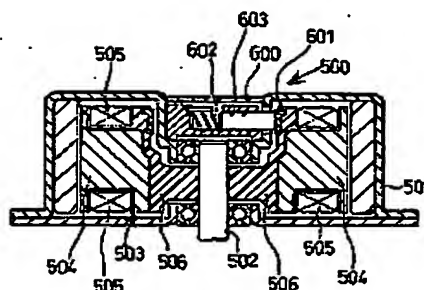
(12)

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【図11】



【図12】



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